ELECTRICAL EXPERIMENTS;

ILLUSTRATING

THE THEORY, PRACTICE, AND APPLICATION OF THE SCIENCE

OF

FREE OR FRICTIONAL ELECTRICITY:

CONTAINING THE

METHODS OF MAKING AND MANAGING ELECTRICAL APPARATUS OF EVERY DESCRIPTION,

WITH

Numerous Illustrative Engravings.

BY

G. FRANCIS, F.L.S.

AUTHOR OF THE DICTIONARY OF ARTS AND SCIENCES; CHEMICAL EXPERIMENTS; THE DICTIONARY OF PRACTICAL RECEIPTS; THE DICTIONARY OF TRADE COMMERCE, AND NAVIGATION THE ART OF MODELLING WAXEN FRUIT AND FLOWERS; MANUAL OF LEVELLING; LITTLE ENGLISH FLORA; FAVORITES OF THE FLOWER GARDEN; GRAMMAR OF BOTANY ETC. ETC. ETC.

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PREFACE.

A WORK entitled "Electrical Experiments" must necessarily be in some degree copied from former treatises: the more especially as the best experiments, and it may be said the best-constructed apparatus, with but few exceptions, are the result of the ingenuity or the reflection of those who studied the subject half a century ago, when electricity was all in all with lecturers as well as with philosophers; and when the discoveries in it rapidly succeeded one another, each more curious, beautiful, or important than its predecessors.

At this earlier period, namely, from about 1740 to the beginning of the present century, philosophers were learning the facts of the science by long series of experiments; lecturers were teaching these facts and giving them popularity by the invention of ingenious apparatus, and showy illustrations, and authors were careful to embody these interesting particulars in their various treatises; hence the works of Priestley, Adams, Cavallo, Ferguson, Hawkesbee, Singer, and others, abound with experimental interest. This time has now past; the experiments proved the facts, the facts suggested the laws of the science, and these becoming known, the learned with few exceptions turned their attention to other matters. If they have condescended to write upon the subject of frictional electricity, they have in all the latter treatises given merely a dry explanation of facts and laws, apparently regarding the detail of experiments as beneath their notice, and forgetting that tyros in science must have their senses gratified as well as their minds enlightened; and equally oblivious of the truth, that a fact illustrated by a pleasing popular

experiment often fixes itself upon the memory, which without that experiment, would fail to be remembered, or even regarded.

The Author of this little work impressed, as he has ever been, with the opinion that the more interesting and amusing a science may be made, the more it will be studied, has endeavoured to collect all the good experiments he has met with elsewhere, and has invented many, as further illustrations of certain parts of the subject. He has been accustomed to make all his own apparatus, and to lecture on natural philosophy for many years. The remarks appended therefore to numerous experiments may be considered practical, and the descriptions also of all the apparatus are original, and it is hoped as plain as they could be made. In speaking however of the originality of the descriptions, it is to be remarked, that some portions of the present work were written by the Author for the "Magazine of Science," of which he was the Editor.

This treatise contains more experiments and illustrations than any other work upon the subject, and all the facts that are known with certainty relative to frictional electricity, although some disputed matters, such as the origin of electricity, and whether there be one fluid or two, are very briefly discussed, they being matters of mere conjecture, and in whichever way they may be decided, will make no difference whatever in the practical and popular development of the science, at least according to our present applications of it.

G. FRANCIS, F.L.S.

ELECTRICAL EXPERIMENTS

INTRODUCTION.

Electricity teaches the laws and effects of a peculiar *substance* or influence called the electric fluid, and derives its name from the Greek word *electron,* amber; the first electrical effects having been observed in that substance.

Daily observations on recurrent phenomena, as well as direct experiments, prove that the whole earth and atmosphere, below, upon, and above the surface, is pervaded by this highly-elastic and subtle fluid, sometimes in a disturbed state, producing then the most stupendous phenomena; at other times in a latent condition, and although then imperceptible, yet not on that account less abundant. If it be not the very essence of life and existence, it acts a very important part in the animal and vegetable economy. Over chemical and meteorological change its power is no less extraordinary. It is easily proved identical with the vivid and withering lightning, the streaming aurora, the rapid whirlwind, the terrific waterspout, the rolling pillars of sand of the desert, and in all probability produces the falling meteor, and the devastating earthquake.

These are some of the more obvious effects of the electric fluid when in that *free* condition in which it is produced by mechanical means; without considering the modifications of it which accompany chemical action, called *galvanic;* or it might be described not merely as regulating solitary phenomena, but as occasioning all the multitudinous effects of chemical composition and decomposition; of crystallization; perhaps of light, heat and combustion; and as analogous to magnetism and gravitation. Although the earth and atmosphere are alone subject to our experimental researches, yet there is just reason to conclude that it abounds throughout the universe as the elemental fire which fills all space, and that it is the mighty power that is employed by the Great Creator, to move, restrain, and regulate the millions of worlds with which it has pleased him to fill the vast and brilliant firmament.

Besides the value of electricity in teaching us the laws and effects of the fluid we have been describing, in thus explaining so many of the grandeı phenomena of nature, and directing us to guard our persons and property in some degree against their destructive effects—the science has other claims to our notice. Its application has been found efficacious in curing some of the most lingering and painful diseases ; the general laws to be remembered are few ; all the apparatus necessary may be made either by ourselves or by ordinary workmen at little expense ; the experiments require for their success only common care and attention, and yet are so brilliant, so varied, and so surprising, as to be a never-failing source of wonder and delight.

It is surprising that a fluid thus universally distributed, and which is capable of such extensive application, should have remained almost unknown until very modern times. Although Theophrastus, who lived more than 2400 years ago, writes that amber, and another body which he called *Lyncurium*, when rubbed, were capable of attracting towards them light substances, yet this solitary experiment, not explained till so many centuries afterwards, was the whole knowledge the ancients had of electricity; and it was not till the latter part of the sixteenth century, when Dr. Gilbert, by discovering that other bodies had similar properties, drew in some degree the attention of philosophers to the subject. Still there was so little to engage public attention, that seventy years elapsed before the electric light was seen. This was discovered by Mr. Boyle, and was enough to stamp with the dignity of a science, what had before been considered as but trivial and unimportant experiments. Attempts were now made to construct a machine by which the fluid should be accumulated in greater abundance. In this Otto Guericke, the celebrated inventor of the air pump was successful, and still more so Mr. Hawkesbee, whose treatise, published in 1709, was the first upon the subject, and the discoveries he made with this improved machine, which was the first one made of glass, far exceeded those of his predecessors. The science was from this stationary for thirty years, when a Mr. Gray directed his attention to it, and arranged bodies into two classes ; the first *electrics*, or those which like amber were capable of being excited, and *conductors*, or those which not capable of excitation themselves, that is, thought at that time not to be so, yet allowed the fluid to pass along them. Not long subsequent to this, M. du Fay, discovered the difference between what were then called *vitreous* and *resinous* electricity. He taught that the phenomena of attraction and repulsion were occasioned by two fluids distinct from and mutually opposed to each other. From this time electricity became more studied, though not popular till the discovery of the Leyden phial in 1746, when it spread rapidly over Europe, engaging equally the attention of all classes of people. Dr. Franklin explained the mode of

action of the phial, and published his celebrated theory of there being but one fluid, the diminution or redundancy of which he supposed to be the cause of all electrical action. Soon the identity of the fluid with lightning was boldly asserted and proved both by Dr. Franklin and L'abbé Nollet at about the same period, the former venturing to bring down lightning from the clouds, and to perform with it all the experiments then known, thus boldly setting the question at rest for ever. Lightning being thus satisfactorily accounted for, the transition to other meteoric phenomena was easy, and in a very brief period the powerful agency of electricity in modifying the surface of the earth, and the atmosphere around it, was firmly established. *Mechanical electricity, free electricity, the electricity of friction, the electricity of tension,* for by all these names this particular part of the subject is called, could go no further; but the wonderful discoveries made during the present century of the intimate connexion between this science, galvanism and magnetism, not only confirm our previous views, but induce us to attribute the facts of all these different departments, as arising from one common cause, and producing effects only so far varied as might be expected from altered circumstances, and the different materials subjected to experiment. The history of this connexion or identity will lead us almost too far from our immediate object; we shall only observe that at the present time so much do these subjects engage the attention of the scientific world, and so numerous and unexpected are the discoveries made in them, that each year opens a still wider field for electrical research, and the laws which regulate the material world.

CHAP. I.

ELECTRICAL ACTION, EXCITATION, AND DIFFERENT STATES OF THE ELECTRIC FLUID.

The electric fluid, though existing in every object around us, is, while in its natural state of rest, not perceptible to our senses; but as soon as by any cause it is disturbed, that which was before latent becomes free, and we are immediately sensible of its presence. If violently agitated, the fluid itself becomes apparent; if less moved, we are only conscious of the disturbance by the effects it produces in attracting towards it the light substances around, and repelling them when by contact the fluid in those bodies also is disturbed. The laws of this *attraction* and *repulsion* must form the subject of a future consideration; at present it will be more convenient to consider the nature of electrical action, and call attention to a few of those common experiments, which show the universality of the electric fluid, and the numerous yet simple operations by which bodies may be artificially *excited*, or thrown into a state of electrical action. However diversified experiments on excitation may be, yet *friction* will be found to attend the whole of them,

and the more attentively the various phenomena are noted, the better founded must be the conviction that this alone causes electrical disturbance. The effect will be in a great measure accordant with the degree of friction employed, and with the dissimilarity of the bodies acted upon; and although it will be seen from some of the illustrations, that evaporation and change of temperature of certain substances causes them to appear electrical, yet each of these operations is attended by a motion of the particles among themselves and against the containing vessel; thus here, as in more obvious instances, friction is produced, though by natural means, rather than by that mechanical rubbing which we are accustomed to employ. The conclusion to which we must come, that friction is the ultimate cause of excitation, is impressed the more strongly upon us by the circumstance that all those bodies which become electrical by heating, cooling, crystallization, or other change of form or temperature, are still more easily and more powerfully excited by the rubbing which effects other bodies.

In performing electrical experiments of any kind it must always be borne in mind that the earth is the grand reservoir of the electric fluid; from the earth it must at all times be taken, and to be retained even for a single moment it must be prevented returning to the earth again; this is easily accomplished by the application of the different properties of *electrics* and *conductors*. The first of these classes of bodies may be excited readily, but will not suffer the fluid to pass along them; the conductors on the contrary are excited with difficulty, but suffer the fluid to escape over their surfaces with great rapidity of motion. Be it observed also, that the electric fluid takes every opportunity to return to a state of rest and quietude, and to keep it disturbed, the body in which it is excited must be *insulated*, or supported by electrics, and no conducting substance brought within its sphere of attraction. In some of the following experiments, indeed in most of them, we witness an electrical action only in one of the bodies subjected to friction, while the rubber or other body is not considered. This however is equally acted upon, and if we take proper means for detecting the electricity of both the rubber and substance rubbed, we shall find that the action is the same in amount in both, but the nature of the action is contrary in the rubber to what it is in the substance rubbed—one exhibiting what is called a redundancy, and which is therefore said to be electrified *plus* or *positively*; the other having a proportionate deficiency, or is said to be electrified *minus* or *negatively*. These two degrees or contrarieties of effect neutralize each other, and thus when two bodies are rubbed together while they remain in contact with each other, no action is apparent; but when that contact is separated, visible effects take place. These preliminary remarks will render plainer the annexed experiments.

Ex. 1. *Attraction of amber.*—Take a piece of yellow amber, warm it, rub it briskly on the coat sleeve, and hold it towards some scraps of bran, filaments of feathers, or other light bodies lying upon a book or a smooth table. The amber being excited by the friction will attract the particles of bran, &c., and hold them suspended. This is the first electrical experiment recorded. The workers in amber are so annoyed by its strong attractive, and easily excitable nature, as to have the tips of their fingers often very greatly affected by it.

2. *Attraction of sealing wax.*—A similar effect takes place when a stick of sealing wax is rubbed and presented to any light matters; they will as before rise up and cling to it. If either the sealing wax or the amber be held towards the bran, &c., before it is rubbed, it will have no effect upon them.

Any thing dry and covered with sealing wax answers the same purpose as sealing wax. The best thing to use is the glass tube mentioned in *Ex.* 9, one half of it in length being heated, and red sealing wax then rubbed on it; this will adhere and form a resinous tube.

3. *Attraction of rubbed paper.*—Take two pieces of white paper, warm them at the fire, place them upon each other on a table or book, and rub strongly the upper paper with a piece of India rubber; the papers will now be found strongly electrical, so as to adhere together with such force that it requires some trouble to separate them, and when separated and then made to approach each other again, they will immediately rush together a second time.

4. *Adhesion of brown paper to a wall.*—Take a piece of common brown paper about the size of an octavo book, hold it before the fire till quite dry and hot, draw it briskly between the side of the coat and the sleeve several times, so as to rub it on both sides at once by the woollen. The paper will now be found so powerfully electrical, that if placed against a wainscot, or the papered wall of a room, it will remain there for some minutes without falling.

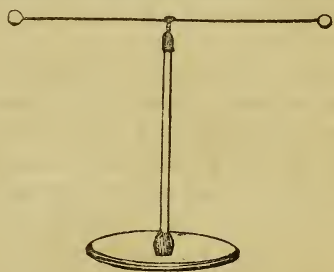
5. *Adhesion of a feather to excited paper.*—If while the paper remain fixed to the wall a light fleecy feather be placed against it, it will adhere to the paper in the same way as the paper adheres to the wall.

6. *Glass plate excited.*—Support a pane of glass, (first warmed) upon two books, one at each end—place some bran underneath it, and rub the upper side with a warm black silk handkerchief or a piece of flannel—the bran will now fly and dance up and down with much rapidity.

This experiment is the only contribution that Sir I. Newton made to electricity, but it was important, inasmuch as it proved what was unknown before, that glass showed electrical effects on the side contrary to that which was excited. The account was read to the Royal Society in 1675. It is very interesting. "Having laid upon the table a round piece of glass, about 2 inches broad, in a brass ring, so that the glass might be $\frac{1}{8}$ of an inch from the table, and then rubbing the glass briskly with the corner of his silk cloak, little fragments of paper laid on the table under the glass began to be attracted, and move nimbly to and fro; after he had done rubbing the glass the papers would continue a considerable time in various motions; sometimes leaping up to the glass, and resting there awhile; then leaping down and resting there; then leaping up and down again; and this sometimes in lines seemingly perpendicular to the table; sometimes in oblique ones; sometimes also leaping up in one arch, and leaping down in another, divers times together, without sensibly resting between; sometimes skipping in a bow from one part of the glass to another, without touching the table; and sometimes hanging by a corner, and turning often about very nimbly as if they had been carried about in the midst of a whirlwind, and being otherwise variously moved, every paper with a different motion. Upon his sliding his finger on the upper side of the glass, though neither the glass nor the inclosed air below were moved, yet he observed that the papers, as they hung under the glass, would receive some new motion, inclining this way or that, according as he moved his finger." This is done much better by a glass, 6 or 8 inches over, at the distance of an inch from the table.

7. *Coffee excited.*—In grinding coffee, particularly if it be fresh burnt, it will be seen to cling around the lower part of the mill, and also around the cup or basin held to catch it—sometimes so strongly as to cover the sides 2 inches or more above the general surface.

These experiments are all examples of electrical attraction, and some of them may be made much more conspicuous to a public audience, if the light matters to be attracted are suspended in some manner, as for example in the following instrument, which is

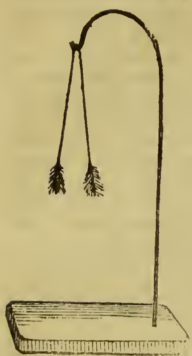


called a *balance* electroscope. Fix a glass rod, a common phial, a stick of sealing wax, or a slip of window glass upright upon a foot or board, cement a needle point upwards upon the top of this; and upon the needle point suspend an equally-balanced slip of very dry wood cut as thin as possible, made perfectly smooth, and about 8 inches long. At each end of the wire fix a scrap of paper, or a small ball made of cork, or the pith of elder.

To make one of these electroscopes or electrical indicators, in the best manner, the foot and supporter should be of brass, and the balance of a fine glass thread; the balls being of pith, and covered with gold leaf.

Ex. 8. *Attraction of electroscopes.*—Hold the excited sealing wax, amber, paper, ribbon or glass of these experiments towards one of the balls of the balance electroscope, the suspended filament of wood will turn round on the pivot, so that the ball will follow the excited matter held to it.

A more delicate, and perhaps more convenient electroscope is made as follows:—The foot is of wood, the upright is a stout wire, bent towards the top as shown in the figure. Upon the hook of this are suspended two pieces of sewing silk, about 6 inches long each, and which have either small disks of white paper, two pith balls, or two feathers tied at the ends. This is called the *pendulum* electroscope. For the above experiments one thread and feather is sufficient.



9. *Glass tube excited.*—This is shown much more conspicuously by using, instead of the sealing wax, a glass tube about 2 feet long, and an inch in diameter; make this perfectly dry and warm at the fire, then rub it briskly with an old black silk handkerchief, made warm. The glass will be powerfully excited, and of course attract with great force the suspended feather.

10. Desaguliers gives the following curious experiments. He says, that when an excited tube has repelled a feather, it will attract it again, after being suddenly dipped into water, in fair weather it will not attract it, unless it hath been dipped pretty deep into the water, a foot of its length in at least; whereas in moist weather an inch or two will suffice. —*Philos. Trans. Abr.*, vol. 8, p. 429.

11. The attraction of water by an excited tube is shown by bringing the tube to a stream issuing from a condensing fountain, which thereupon is evidently attracted to it. —*Desaguliers.*

12. *Recession of charged objects.*—Hold the glass tube in contact with the suspended feather for a short time, the feather which at first was attracted will soon become what is called *charged*, that is filled with electrical fluid. It will in this state become fleecy, the filaments will diverge from each other, and the feather *fly away* from the glass tube, and most likely adhere to the wire support of the electroscope. Sometimes if the tube be powerfully excited, the feather will fly backwards and forwards, giving a good example of electrical attraction and repulsion.

Note.—It is here to be observed, that we use the terms repelled, charged, filled with electrical fluid, &c. in their popular sense only, so also until we can consider more fully the nature, effects and laws of electricity, cannot enter into a discussion, whether there be in reality no repulsion at all, or if there be one electric fluid or two.

13. *Repulsion of electrified feathers.*—Let there be two feathers suspended upon the electroscope by different silk threads, they will both adhere at first to the glass, and then recede from it, and also from each other. If there be three or more feathers, the same effect will be exhibited.

14. *Feather driven about the room.*—If, while still excited, a light fleecy feather be brought near, it will at first cling to the glass rod, and afterwards fly away from it, and may be driven about a room, by holding the glass between it and any surrounding object. If it should touch any thing not electrified, it will fly back to the glass again. It will be observed, that the same side of the feather is always presented to the excited tube.

15. *Electrified hair.*—Another instance of electric repulsion is seen when a bunch of long hair is combed before a fire, "each particular hair will stand on end," and get as far as possible from its neighbour.

The above experiments show the electric disturbance of various bodies, so as to inform us that some power exists which is called into action by friction, assisted by perfect dryness of the materials employed, but they do not communicate any intelligence of what this power really is; yet a very trifling increase of the intensity of any of the foregoing will render the fluid itself perceptible to our corporeal senses, sight, hearing, feeling, smelling, and as we shall show hereafter taste also, though we believe this cannot be made perceptible by the simple means we are now employing.

The ancients were quite unacquainted with any other electric effect of amber, but that recorded in the first experiment. Dr. Hall discovered many other electric properties of it, as recorded in *Philo. Trans. Abr.*, Vol. 2, He says—

16. "I found by gently rubbing a well polished piece of amber with my hand in the dark, that it produced a light; whereupon I got a pretty large piece of amber, which I caused to be made long and taper, and drawing it gently through my hand it afforded a considerable light. I then used many kinds of soft animal substances, and found that none did so well as wool. And now new phenomena presented themselves, for upon drawing the piece of amber through the woollen cloth, and squeezing it pretty hard with my hand, a prodigious number of little cracklings were heard, and every one of these produced a little flash of light; but when the amber was drawn gently and lightly through the cloth, it only produced a light, but no cracklings; but by holding one's finger at a little distance

from the amber, a large crackling is produced with a great flash of light, and what to me is very surprising is, that upon its eruption it strikes the finger very sensibly, wheresoever applied, with a push or puff like wind. The crackling is full as loud as charcoal on fire, and five or six cracklings or more, according to the quickness of placing the finger, have been produced from one single friction, light always succeeding each of them. Now I make no question, but upon using a longer and larger piece of amber, both the cracklings and light would be much greater, because I never yet found any crackling from the head of my cane, though it is a pretty large one. This light and crackling seem in some degree to resemble thunder and lightning." Dr. Hall also states that light can be produced from jet, sealing wax and the diamond.

17. Break a large lump of loaf sugar in the dark, or pound it in a mortar, when it will appear covered with a beautiful lambent blue flame. When grocers are sawing up loaves of sugar as samples, the dust is most luminous and beautiful.

18. *The electric light and snapping obtained from paper.*—Excite a piece of brown paper, after having made it quite hot before the fire, as in *Ex.* 4; make it adhere to the wall in a dark room, and immediately tear it from the wall, a light attended by a faint snapping noise will arise. This is the electric spark.

19. The same is very perceptible, if the two pieces of white paper, excited as in *Ex.*3, are taken and torn asunder in the dark.

20. *Electric light and odour obtained from quartz.*—Rub or grate together two round uncut stones of quartz, calcedony, cornelian, &c., and a strong phosphoric light and odour will be produced, showing another peculiarity: viz., that the electric fluid is perceptible to our sense of smelling.

21. *The spark felt.*—Support a round plate of metal upon the top of a very dry wine glass. Excite the brown paper as in *Ex.* 4, and place it on the metal plate; if now you hold your knuckle quickly to the metal plate, a small but very perceptible spark will pass from the metal to the hand, showing the fluid is perceptible to the touch, and also that it will pass from one body to another, for it is the fluid from the excited paper, which passing through the metal is felt by the hand.

22. *Sensation of cobwebs.*—Hold the excited glass tube close to the face, a sensation like that of cobwebs spread over the face will be immediately apparent, and the hair will be sensibly moved at the near approach of the tube.

23. *Shock from a cat.*—Take up in the lap a black cat which has been lying for some time before the fire; hold it by one hand under the throat, and with the other hand rub the cat several times along the back. The hair will soon become so excited, and overcharged with the electric fluid, that a complete shock may sometimes be felt, and generally a succession of small sparks. We need scarcely observe, that Miss Pussey must be a consenting party. This experiment, as indeed do all of an electrical nature, succeeds best in frosty weather.

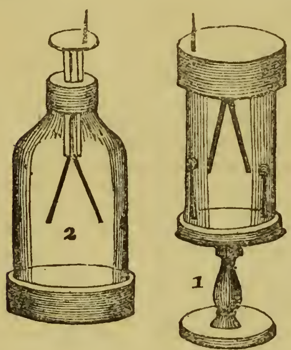
24. *Metallic ball electrified.*—Suspend from the ceiling a metallic ball by a silk cord, and touch it with the excited glass tube. This ball will now attract the feathers or the balls of the common electroscope in the same manner as the glass rod itself does. This shows that electricity is communicated from one body to another, as it is very evident that the metallic ball became electrical by contact with the tube.

The above experiments, and which show the various effects of the electrical fluid, are made with somewhat brisk and continued friction, and therefore produce effects of sufficient plainness and strength to be perceptible to us without any instrument of superior delicacy. It will naturally be concluded, that a less degree of friction will still produce similar effects, although they will be proportionably less in amount. Indeed we shall soon have occasion to show that the most trivial actions we do, and the most casual operations of nature, require only favorable circumstances to make their electrical character apparent. Among these circumstances, the most important is, that we should perform the experiments with care, and the second, that the instruments we use to detect the disturbance of the fluid should be of extreme delicacy. These instruments are called *electroscopes* and *electrometers*. The first indicates an apparatus which shows that a disturbance has taken place in the fluid of an excited body, as is the case with the *pendulum* and *balance* electroscopes we have described, and the other, (the electrometer) is capable of measuring the exact amount of this disturbance. It is necessary to describe one of each of these, that we may see the effects produced by other, and less obvious, or at least less powerful modes of excitation.

THE GOLD LEAF ELECTROSCOPE.

The gold leaf electrometer is made of two forms, as shown in the following cut. In that marked 1, and which is called from its inventor, *Bennett's gold leaf electroscope* consists of a wooden foot, which supports a glass tube about 2½ inches wide, and 5 long. This has two slips of tin foil pasted on the opposite sides as represented. The cylinder is closed

at top by a brass cap, which fits tight round the sides, but takes off and on, in order that if the two slips of gold leaf which hang from the middle of the cap in the inside should become broken, they may be repaired. The cap should not in any other case be removed. The gold leaves are about $3\frac{1}{2}$ inches long, and $\frac{1}{2}$ an inch wide; they are best fastened on by a little piece of flatted brass, soldered to the inner side of the cap, and the leaves, attached by gum water, gold size, paste, or any thing similar. They should hang so as to touch each other when not in an electrified state, and when divergent, as shown in the cut, they should approach to the slips of tin foil on the glass. The cap has occasionally a point which screws upon it, as shown; this however is never used, except in trying experiments upon the electricity of the atmosphere.



Sausseur's gold leaf electroscope, which is represented in fig. 2 of the above cut, differs from the former in the manner in which the gold leaves are insulated. The cap is a flat plate, with a wire soldered beneath. The gold leaves are soldered at the lower end of the wire, and the whole wire is inclosed in a glass tube. The outer surface of this tube is best covered with sealing wax, as the insulation of resinous substances is much better in damp weather than that of glass, which rapidly attracts the moisture of the breath, or of the apartment. The diameter of the glass may be 4 inches, the height of it 8 inches. The size of the plate at top from 2 to 4 inches, as most convenient. The cap which incloses the top of the glass, and into which the glass tube is cemented, may be of wood or metal; the former is preferable.

A cheap and good substitute for the above may be made of a common six-ounce phial, a wire passing through the cork of it, having the gold leaves within the phial, and a brass ball or a bullet above. A lamp glass, also, with a cork above and below, (ball and gold leaves similarly arranged,) answers every purpose, the bit of card also is of little consequence; and let it be remarked, once for all, that whenever glass apparatus is employed, it must be kept perfectly dry, slightly warm, and free from dust. Of so much consequence is this, that should there have been a failure in any of the simple experiments, it most probably has arisen from neglect of this precaution. There are numerous variations of this instrument, according to the purposes for which they are required. One of extreme delicacy, though not so much so as that with gold leaves, is made with two fine strips of straw, suspended on little wire loops. Another is furnished with two extremely delicate silver wires, with small pith balls attached: this is used chiefly for experiments upon the electrical state of the atmosphere. This with numerous other electroscopes wil be described hereafter.

Note.—We would remind the young electrician that the *whole* of his apparatus may be made by himself with ordinary care, and that he may do so with greater facility, we will fully describe the various parts of each instrument. Let him at all times remember to round off all sharp edges and corners, and to make the wood work smooth. Every thing in glass, except plates, whether cylinders, tubes, rods or handles, he may purchase at per lb., at the glass works, Holland Street, Blackfriars. Tinfoil may be cheapest bought at a pewterer's. A maker of it lives in Brown's Lane, Spitalfields, London. A roll 5 feet long, and 10 inches wide, costs 5*d*, or a smaller roll $3\frac{1}{2}d$. Tinfoil for electrical purposes may be as thin as possible; it is best put on to wood or glass with common paste. When silk is used, let it be always black, except when otherwise specified. The best varnish for electrical apparatus is copal varnish or shell lac varnish; and if they are required to be ornamented with a colored varnish, let it be by two or three coats of sealing wax dissolved in spirits of wine, laid on with a small brush. Both the shell lac varnish and the sealing wax varnish are easily made by breaking the lac or the wax in small pieces, putting it in a phial with spirits of wine, brandy or whiskey, enough to cover it, and then placing the phial on the hob till the resinous substance is dissolved. These varnishes dry in a few minutes, but copal varnish takes two days. The mode of action and degree of susceptibility of these electrometers are shown by the following series of experiments:—

25. Take the paper which was before experimented with, and after again exciting it well, lay it upon a plate of tin, supported by a dry wine glass. Immediately and suddenly apply the knuckle to the under surface of the tin, and a spark will be felt. A better substance than tin would be a round piece of

wood 6 or 8 inches in diameter, ½ an inch thick, rounded at the edges, and covered neatly with tin foil, as by this means sharp edges are avoided.

26. Suspend a pair of pith balls to the under surface of the plate of tin or wood; place the excited paper upon it as before, and observe that the pith balls will recede from each other, or show electrical repulsion. This then explains the mode of action of the electroscope, and the appearance it presents. In this experiment the disturbed fluid of the paper acts upon the fluid of the metal plate, and that upon the fluid in the pith balls. In gold leaf electroscopes the fluid is in like manner disturbed, and of course according to its amount or degree of disturbance so will be the greater or less divergence of the gold leaves.

27. Hold near the above instrument any of the excited bodies used before—such as the paper, or the glass rod, and the gold leaves will diverge to a considerable distance from each other, and remain so for some time. A well-excited glass tube will stimulate it at a distance of 2 or 3 feet, and must not be brought too rapidly close to it, or the gold leaves will be rent to atoms by the violence of the action.

28. Brush the cap of the electroscope with the feathery part of a quill, and the gold leaves will instantly diverge.

29. Give the cap a blow or two with the corner of a black silk handkerchief, previously warmed, and the friction, small as it is, will be found to have the same effect as before.

30. Take a knife, with a glass or ivory handle, and cut some small pieces off a slip of deal, so that they shall fall upon the cap as before. Each piece carrying down with it a portion of the fluid disturbed, will, in a similar manner, affect the instrument.

31. After playing a tune upon a violin with a well-rosined bow, hold the bow towards the cap of the electroscope, the gold leaves will immediately diverge.

32. Sift some steel, brass, or other metallic filings, upon the cap of the electroscope, from out of a metallic sieve. These filings become electrical by the friction merely of passing through the holes of the sieve, and will consequently affect the gold leaves. The same may be done with charcoal, putty powder, black-lead, lime, and numerous other bodies.

33. Let the metallic sieve out of which they are sifted be held by a sealing wax or dry glass handle. Sift some metallic powder through it, but at a distance from the electroscope; then hold the sieve to the electroscope, that will be found to be excited; and if the means be taken which are explained in the after-part of this chapter to ascertain the nature of the excitement, it will be found that the sieve is in a contrary state to that of the powder.

34. *Bombazine excited by rending.*—Warm a piece of this stuff at the fire, or any other kind of material formed of two substances, such as woollen and silk, silk and cotton, silk and hair, &c.; when warm and dry, draw out the various threads, of one of the substances, and put them on the cap of the electroscope; it will immediately become affected. The weavers of bombazine are well aware of these electrical properties.

35. Melt some chocolate in an iron cup, adding a few drops of olive oil; place the cup upon the top of the electroscope to cool, as it cools, it will become electric, and show this by the divergence of the gold leaves.

36. Clean a piece of dry glass with whiting, and let the particles fall upon the top of the electroscope, they will sensibly affect it. Dust brushed off a coat will generally affect it in like manner.

37. Break a stick of sealing wax in half, and hold one of the broken ends towards the cap, and the gold leaves will diverge.

38. Varnish a piece of glass; when the varnish is dry, scrape some of it off, letting it fall upon the electroscope; this also will show a sensible effect.

The student will perhaps desire to vary these experiments, and being observant will soon ascertain that there are apparent anomalies in the mode of action, or in the effect produced, for which he will, until such are explained, be unable to account for.

39. For example, let him hold the glass tube to the gold leaf electroscope, so as to make the leaves diverge, but so as not to touch it; he will observe that immediately he removes the exciting cause, the effect will cease; as the glass is withdrawn, the leaves will collapse. Now let him touch the cap with the excited glass, and then withdraw it. The gold leaves will now continue to diverge, and not collapse as before.

40. While they are thus divergent, let the glass still excited be made to approach a second time, the leaves will recede still farther from each other than before.

In the former of these experiments the electricity is *induced;* that is, no electricity is really communicated to the leaves, but the approach of the excited electric has had sufficient power to disturb the fluid of the whole apparatus, and to drive it to the extremity of the gold leaves; they being both electrified repel each other, but the effect is transient only, and when the exciting cause is removed, of course the effect ceases. In the latter

experiment, in which the exciter touches the apparatus, it positively charges it with some of its own fluid, and therefore it is in this case not merely the extremity of the gold leaves which become electric, but the whole apparatus, and they being the only delicate parts of it, show that it is so; this then is an instance of *accumulated* or communicated, and not induced electricity. The next two or three experiments open to us a new field of inquiry.

41. Roll up a band of flannel, warm one end of it at the fire, and hold it by the other. Excite the sealing wax by the warmed end, hold the excited wax to the gold leaf electroscope, and it will show the usual signs. Next remove the wax and hold the flannel; this will also show that it is excited. Next hold them both together towards the instrument, and no effect will be apparent.

It is then evident that in every instance of friction, as there must be two bodies rubbed together, so both of them become equally excited. In the one body the fluid accumulates, and that body becomes *positively* electrified; the other is to an exactly equal degree deprived of its fluid by the first, and it becomes electrified *negatively*, and these two degrees of disturbance are such as exactly at all times to destroy each other, as was proved in one instance in the last experiment, where the wax and flannel being held together produced no effect. Yet although this is known to be the case, the general result of the operation of presenting the flannel and the wax is the same, the gold leaves were divergent in both instances; this is because two bodies electrified, whether negatively or positively, repel each other. When the wax was presented, as wax when rubbed by flannel becomes negative, it attracts to itself the fluid of the apparatus. This is collected near to the wax, and the opposite end is consequently deficient; when the flannel is presented, as that is positive, it drives the fluid of the apparatus to as great a distance as it can, and the gold leaves are consequently divergent from excess of fluid. These effects, though apparently the same, may be proved to be contrary to each other, as follows:—

42. Touch the cap with the excited wax, so that the gold leaves are affected by communicated electricity, then bring the wax near them a second time, and they will diverge still more, but bring instead of this the excited flannel towards them, and they will collapse; in fact, the fluid in the flannel being of a contrary character has annulled the effect of the wax.

43. Next, while the leaves are divergent with negative electricity by the wax having touched them, excite a glass tube and hold it towards the instrument. The leaves will collapse as in the last instance, showing that the effect of the flannel in the last experiment, is the same as that of the glass in this, or that they are both electrified positively by the friction that has been used.

44. Suppose that the glass tube in the last experiment be rubbed by flannel, instead of the silk handkerchief recommended in *Ex.* 9, the effect would be the same, as may be tried; if so, the flannel with which it is rubbed must be negative; whereas, in the last experiment the flannel was positive; thus the same substance may be positively or negatively electrified, according to circumstances.

45. Try an experiment similar to *Ex.* 44 with a glass tube, rubbed with a black cat's skin, and the glass is then negative, and the skin positive.

46. Roughen the glass, and rub it with silk, and the rough glass is then negative, and the silk positive.

47. Rub the sealing wax with a piece of tinfoil held tightly in the hand, and upon trying the effect, the wax will now be found positive, although in all our former experiments it has been negative.

It is important then to observe, that no body has any peculiar character of fluid inherent in it. Glass and sealing wax only show their ordinary effect under ordinary circumstances, each as we have seen takes the place of the other occasionally; this however was not suspected at first. M. Du Fay, who ascertained the negative character of the latter, and the positive character of the glass, imagined that these effects were constant, so much so as to designate the two states of negative and positive, by the terms *resinous* and *vitreous*; supposing, and in which he has had many followers in our day, that there were two distinct fluids, the disturbance of which was at all times simultaneous and equal. It was not till the experiments of Mr. Canton in the latter part of the year 1753, and of Mr. Wilson soon afterwards, that showed the impropriety of the terms vitreous and resinous, though they were not able to affect the question of whether there is one fluid or two.

These experiments may be varied without end, and we have by them a ready means of ascertaining at all times the electric properties of all substances which will admit of friction; for we have only to electrify any electroscope with one substance, the effects of which we are certain, and we can by that test all others.

48. Excite a glass tube, let it touch an insulated body, for example, the balls of the pendulum electroscope, and then hold the body to be tested close to it, if the balls

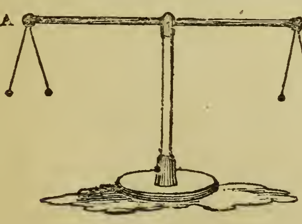
recede still more when electrified by this body, it is electrified positively, and if they collapse, it is electrified negatively. The two states of the fluid may also be shown, as follows :—

49. Excite a rod of sealing wax, and another of glass, both by flannel. Hold them one on each side of a pith ball suspended by silk, the ball will vibrate backwards and forwards from one to the other. The moving body may be made in the shape of a fly or spider.

In all the above experiments it must be observed, that the excited body to be tested must be held towards the same part of the apparatus as the test object was, or the result will be indecisive, and may even appear contrary to what it is in reality. As before observed, when an excited glass tube is held to the electroscope, if it do not touch it, it drives the fluid to the farther extremity, which extremity is the part that shows the positive effect. If it be held towards that extremity, immediately the effect may cease, because it drives that redundancy to the other end. This curious effect may be tried thus :—

50. Make a pendulum electroscope with a glass support, and linen threads instead of silk ones, or what will do as well, damp the silk threads with the mouth, touch the top of the strings with the excited tube, and the balls will diverge, the fluid being driven to them; then present the tube a second time also at the top, and they will diverge still more; hold it sideways towards them, and although they will approach the tube, their divergence will be but little altered. Hold the tube beneath them, and they will collapse. The effect of the induction now produced by the tube being to repel the fluid towards the top, and consequently away from where it shows itself.

51. Try the same experiment with an electroscope made of the following shape; the



cross arm being a metallic wire, the support being glass. The excited glass tube being allowed to touch the end A, and then being withdrawn, both pairs of pith balls will show signs of divergence. Hold the glass tube a second time to the end A, but without touching it, the pair at A will partly collapse, while that at B will diverge still more. Reverse the experiment by holding the excited glass to B, and the balls at B will collapse, while those at A will increase their divergence.

Instead of giving other experiments to this, which necessarily have a great sameness in their result, we have appended the following table, taken from *Cavallo's Electricity*, and by the inspection of which the positive or negative result of the friction of all ordinary substances may be at once ascertained.

CAT SKIN is rendered *positive* by friction with every substance with which it has hitherto been tried.

SMOOTH GLASS is *positive* with every substance, except cat skin. (We believe that this will hold good with several other furs; for example, that of a black rabbit.)

ROUGH GLASS is *positive* with dry oiled silk, sulphur and metals; *negative* with woollen cloth, quills, wood, paper, sealing wax, white wax, and the human hand.

TOURMALIN is *positive* with amber, and the blast of air from bellows; *negative* with diamonds and the human hand.

HARE'S SKIN is *positive* with metals, silk, loadstone, leather, the hand, paper, and baked wood; *negative* with other finer furs.

WHITE SILK is *positive* with black silk, metals, black cloth; *negative* with the hand, paper, hair, and weasel's skin.

BLACK SILK is *positive* with sealing wax; *negative* with hare's, weasel's, and ferret's skin, the hand, brass, silver, iron, and white silk.

SEALING WAX is *positive* with some metals; *negative* with hare's, weasel's, and ferret's skin, the hand, silk, leather, woollen cloth, paper, and some metals.

BAKED WOOD is *positive* with silk; *negative* with flannel.

Mr. Singer justly remarks, that " the result of experiments of this kind is much influenced by the state of the bodies employed, and the manner in which friction is applied to them. In general, strong electric signs can only be produced by the friction of dissimilar substances, but similar substances, when rubbed together, so that the motion they individually experience is unequal, are sometimes electrified, and in such cases, the substance whose friction is limited to the least extent of surface is usually negative; thus the violin bow of *Ex.* 31, was positive, while if the strings had been also tried, they would have been

found negative." Another remarkable circumstance is that color makes a considerable difference, black and white having in many cases a contrary effect. The following curious experiments on ribbons, stockings, &c., will illustrate many of these effects :—

52. *Adhesive Ribbons.*—Take two silk ribbons, one black, the other white, each about 3 feet long; warm them at the fire, holding them up flat against each other with one hand, draw the thumb and fingers of the other hand briskly over them several times; they will thus become powerfully excited, and although the upper ends of the ribbons be forcibly separated to the distance of a foot or more, the lower ends will still cling together. The black will be negative.

53. Instead of a black and white ribbon, use two that are white, or two that are black; excite them in the same way, and they will become repellant of each other, both being positive if white, and negative if black.

54. Take a single ribbon, either white or black, warm it, hold it by one end, while another person holds the other end; draw backwards and forwards over it briskly any negative electric, such as amber, sealing wax or rosin. The ribbon will be excited positively, whether white or black. If instead of being held at each end, it be laid upon a quire of smooth dry paper, and then rubbed, the effect will be the same. If positive electrics be drawn over the ribbons, they will be excited negatively.

55. A strip of flannel and black ribbon will excite, and show the same effect as two differently colored ribbons.

56. Dry two white silk ribbons at the fire, extend them on any smooth plane, draw the edge of a short ivory rule over them several times. While they continue on the plane, they do not seem to have acquired any electricity; yet, when taken up separately, they are observed to be negatively electrified, and repel each other. When they are separated from each other, electric sparks may be sometimes perceived between them; but when they are again put on the plane, no electrical appearances are seen without a second friction.

57. Place the ribbons on a rough conducting substance, rub them as before, and they will, on their separation, show contrary electricities, which will also disappear when they are joined together. The upper ribbon is negative, the lower positive.

58. Place the white ribbons which have been rubbed upon the rough surface, upon that surface again after they have been separated from it, and suffering them to remain there a few minutes, they will then upon being separated be found to attract each other; the uppermost being positively, the lowermost negatively electrified.

59. When two ribbons are made to repel each other, draw the point of a needle lengthways down one of them, and they will rush together.

60. Bring an electrified ribbon near a small insulated metallic plate—it will be attracted but feebly. Bring a finger near the plate, a spark will be observed between them, though both together show no signs of electricity; on the separation of the ribbon they again appear to be electrified, and a spark is perceived between the plate and finger.

61. Lay a number of ribbons of the same color upon a smooth conducting substance, draw the ivory rule or paper knife over them, take them up singly, and each will give a spark where it is separated from the other. The last will do the same with the conductor, and they are all negatively electrified. Take them from the plate together, and they will all endeavour to recede from each other.

62. Let them be placed on a rough conducting substance, and then be separated singly, beginning with the lowermost, sparks appear as before; but all the ribbons will be electrified positively, except the uppermost, or that upon which the ivory knife has acted. If they receive the friction upon the rough conductor, and are all taken up at once, all the intermediate ribbons acquire the electricity of the highest or lowest, according as the separation is begun with the highest or lowest.

63. If we take two ribbons of white silk, cut from the same piece, and make them rub against each other, while they cross at right angles, the piece which crosses the other transversely assumes negative electricity, and the other becomes positive,

64. The same effect is sometimes produced by rubbing two sticks of sealing wax, placed at right angles with each other. It would appear from these, and other experiments, that the substance which is subjected to the greatest friction becomes negative, and the other positive.

Mr. Symmer, an electrician of the last century, made some very curious observations and experiments on silk stockings. He was accustomed to wear two pair at the same time, and from the remarks he made upon taking them off and putting them on, the following experiments are deduced :—

65. *Electrified stockings.*—Put upon the same leg a worsted stocking, and over this a silk one. Warm the leg at the fire, and rub the hand over the stockings. This done, slip off the silk stocking suddenly, and the two sides of it will recede from each other, and

the whole retain the same shape as if the leg still remained in it.

66. If the stockings are both of silk, the one white and the other black, and they be warmed, rubbed, and then pulled off together, they will show no sign of electricity; but on pulling off the black one from the white a crackling of sparks may be heard, and a light may be perceived upon their separation, if performed in the dark.

67. When the stockings are separated, and held at a distance from each other, both of them appear to be highly excited—the white stocking positively, the black negatively; and while separated they are both inflated, as in *Ex.* 65.

68. If the stockings be of different colors they will attract each other; if of the same color they will repel, in the same way as the ribbons of former experiments.

69. Let the stockings thus inflated by different electricities be suffered to meet; the inflation immediately subsides, and they stick together with considerable force, each becoming quite flat. If they be again separated they will be inflated almost as strongly as at first.

70. Take a ribbon of hot paper, and draw it backwards and forwards upon a dry linen cloth, laid on the knee, and the paper will always be negative.

71. If rubbed against a metal it will become negative, unless the latter has received a high degree of polish, when it will sometimes become positive.

72. When paper is rubbed against white silk it is generally negative, unless the silk be very hot, when the paper often becomes positive. With black silk it always becomes positive, except the silk be worn thin, when the paper is generally negative.

73. Draw a black or white silk ribbon backwards and forwards over a piece of metal, and it becomes negative, whether the metal be polished or not.

74. Take a piece of silk cloth, and swing it backwards and forwards in the air of a dry room, and it will show signs of negative electricity when held to the electrometer.

75. A ribbon of silk, paper, or linen, rubbed against the skin of an animal still covered with hair, will always become very strongly and negatively excited.

CHAP. II.

ELECTROMETERS. EXCITATION BY HEAT, PRESSURE, CONTACT, CLEAVAGE, CHEMICAL ACTION, AND EVAPORATION.

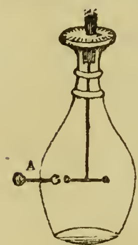
It has been already observed, that friction is the cause of electrical disturbance, and that its extent agrees mainly with the degree of friction employed; thus there are many operations in which friction is produced in a very small degree—these are, no less than more obvious examples, proportionably productive of electrical appearances. The mere contact of substances, the separation of two bodies which are united, heating, cooling, evaporation, impulse of steam, chemical actions, animal muscular motion, even the slow vegetation of plants and seeds give out certain electrical signs; nay, it is probable that there is not an action we can do, or a change of motion in an inanimate object we can occasion, which does not in a greater or less degree disturb the electrical fluid, sometimes exhibiting it in one character, and sometimes in another. Thus clouds drifting through the atmosphere, the wind impinging upon the earth's surface, the rolling of the ocean upon the shore, the rise and fall of dew, the occurrence of rain, hail, snow, and numerous other phenomena of daily occurrence do, in their immensity, produce often well-known effects. These are apparent to us when insulated as in our ordinary experiments; in other cases

though equally produced, yet not observable, because of the want of those circumstances, which would have prevented these sudden effects from being as suddenly dissolved. We can however show by our contrivances, that these electrical disturbances must take place in all cases, even where the most minute substances are concerned, and where the degree of friction is so small that it can scarcely be estimated.

The experiments of Coulomb, and others of later date, upon this electricity of pressure, contact, &c., are very interesting and varied; many of these can be well shown by the foregoing electroscopes; but there are others of them of too delicate a nature to show their effects to even the most susceptible of the instruments we have hitherto described; indeed, many of them would never have been witnessed at all, unless Coulomb had contrived an electrometer which could be acted upon by less powerful impulses than those we have hitherto found it necessary to depict or describe. The following is the most delicate instrument of the kind:—It is called

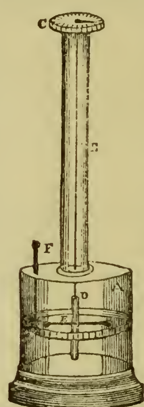
COULOMB'S TORTION ELECTROMETER.

It consists of a glass vessel, about the diameter of a common tumbler, and 6 or 8 inches high; such glasses are made for the use of the confectioners. We have represented it as made of a common pint decanter, as that will answer the purpose well, as would also a wine bottle, or large phial. Through the top passes an untwisted raw silk thread, 4 inches long. The glass decanter is graduated at the top by a piece of card fastened on to a cork; the card is graduated to 360°, and the cork which fits the decanter has a hole cut through it sufficiently large for the silk thread to pass through it, and to have, at all times, sufficient room to work without touching the sides of the hole. There is a little hand on the upper end of the filament of silk, and at the lower end a very fine gum lac or red sealing wax thread, having at each extremity a small knob. This lac needle and its knobs weighs only ¼ grain. A small hole is drilled in the side of the vessel at A, through which passes a fine wire, terminated at both ends with small balls. It is cemented in the side of the glass by sealing wax. When an excited body is made to touch the knob at A, the knob at the other extremity will acquire the same electricity as the excited body. This electricity it will communicate to the knob of the lac needle, suspended by the silk thread, which was previously almost in contact, and the two knobs will repel each other. The moveable knob will therefore be repelled from that which is fixed, and the quantity of electricity will be proportionate to the distance to which it is driven. By means of the micrometer at top, it may be set at any position, so as in other cases to show the degree of attractive force. The following instrument, called *Coulomb's electrical balance*, is made upon precisely the same principle, and is of great delicacy.



COULOMB'S ELECTRICAL BALANCE.

A is a glass vessel, fitted into a stand at the foot, and having a circular portion of its circumference graduated. Upon A is fixed a long glass tube B, at the top of which is a circular scale of ivory C, with a small hand moveable around the centre. Upon the centre of motion of this hand is suspended a single untwisted fibre of silk, which passes down the tube B, and into the vessel A, where it is terminated by a small piece of straw D, across which passes a wire and light ball E, forming a balance; also through the top of A passes the wire F, which has a ball at each end; one then of course will be without the vessel A, and the other within it, and exactly opposite to the ball E. When the upper ball F is electrified, it acts upon the ball E, repelling this to a certain distance, which distance, and consequently the degree of electrization, is indicated by the graduated scale on the side of A.

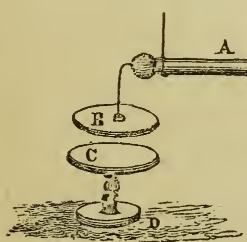


These instruments are superior for delicate experiments to those electroscopes formerly described, because the degree of tortion which they undergo is a true criterion of the power exhibited, whereas in the pendulum electroscopes gravitation acts very differently upon them at different degrees of divergence of the leaves, so that a repulsion of the leaves of

gold leaf, of the pith balls, feathers, &c., as the case may be, of 40°, does not necessarily imply a double impulse to that action which shows 20°; on the contrary, it will be much more than this. The balance electroscope, (page 5,) is not so unequally influenced by gravitation, but is too rude an instrument for some of the very minute experiments which the student would sometimes find it requisite to perform.

The manner in which the state of the electricity, whether positive or negative, is discovered by the tortion electrometer, is by exciting it by a known body, as glass, and then observing if the ball be attracted or repelled by the approach or contact of the substance to be tried.

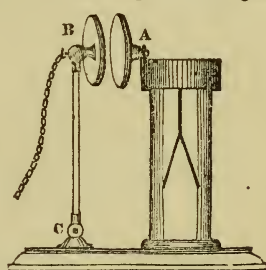
Other instruments of extreme delicacy, and which we shall find it for the future sometimes convenient to use, are *Volta's condenser* and *Bennett's electrical doubler.* We will previously to describing them show the principle upon which they depend. When an insulated conductor is opposed to one which is not insulated, it has its capacity of electrical change increased by that proximity, and is more susceptible of an increased or diminished quantity of electric fluid than when freely insulated, because in the state of approximation a much more considerable charge will be required to produce the same intensity, or tendency to equilibrium. Now, were the contiguity of the opposed plates permanent, no advantage would be obtained; for the principle which renders the insulated plate susceptible of more extensive electrical change, also prevents it from rendering that change evident; it is therefore essential, that the plates should be so arranged as to admit of alternate proximity and separation; for example—



Suppose the metal plate B be suspended by a wire A, and A itself suspended by two silk threads. Also, suppose that C is a second metallic plate placed a little below B, and that B is connected with the ground. Touch A with the excited glass rod, it will of course communicate a charge to B. If now the plate C be made to approach B gradually, yet not so close as to take a spark, it will influence the fluid in B to such an extent as to enable B to take a greater charge than before; and the nearer C is brought to B, provided no spark pass between them, the greater will be the effect of C approach. Now touch A a second time; this new fluid will act still more upon that in C, and as action and reaction are equal, B will be acted upon a second time, and so on for several times. By this means B will be soon charged to a very much greater extent than it would have been if C had not been present, and an impulse, not sufficient to affect the gold leaf electroscope singly, may thus be made perceptible. The following instrument,

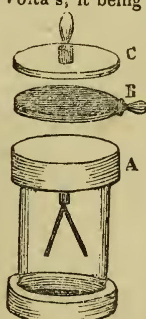
VOLTA'S CONDENSER,

Shows a pair of these condensing plates attached to a gold leaf electroscope. The plate A is connected with the cap, and is of course insulated. The plate B is supported upon glass, but is connected with the ground by the chain; it turns upon a joint at C. It is sometimes connected with another condenser, when the plate B becomes insulated by taking off the chain. The two plates have a thin coat of gum lac varnish on their inner sides, to prevent contact, and in consequence entire dispersion. To use the instrument, touch the cap or plate A with the excited body, B being withdrawn, then approach B to A, and touch A again; it may afterwards be made to touch a third or fourth time, or more, until the gold leaves show signs of divergence.



BENNETT'S ELECTRICAL DOUBLER.

This instrument is an improvement upon Volta's, it being more susceptible. It consists, as the cut represents, of a simple gold leaf electrometer, the top of which is a flat metallic plate, marked A, of a similar plate B, which has a glass handle, and of a third plate C, also with a glass handle. The plates C and B are covered on their under-side with sealing wax varnish. To use the instrument, first put the plate B upon A, touch the plate B with the finger, and then before the



finger is removed, touch the plate A with the object to be tested. Take away the object, and also the finger; take up B by its handle. Place C on B, and touch C with the finger. By this a portion of the electric fluid is disturbed in C, so that C becomes electrified plus, or minus, in the same manner as A. Place B upon A, and touch B with the finger, and apply the edge of C to A; the electricity of C will then flow to A. Remove C, take the finger from B, and raise B from A. Proceed in the same manner for three or four times more, until so much electricity is accumulated in A, as to occasion the divergence of the gold leaves. We will now show the use of these instruments by experiments.

The mode chosen by M. Becquerel to show most of the following experiments was to form the substances to be tried into small discs, about one-tenth of an inch thick; to fix each to a varnished glass rod by way of handle; to take one of these handles in each hand, and squeeze the two discs together. After separating them, each disc has to be presented to a delicate electrometer; a single pressure is often sufficient to repel the small disc of Coulomb's tortion electrometer, but by repeating the contacts Dr. Thompson says any electrometer may be affected.

ELECTRICITY BY PRESSURE.

Ex. 76. *Pressure of Iceland spar.*—Hauy directs us to press in the hand a piece of Iceland spar; then by holding it to the electrometer we shall find it electrical even by this very minute amount of friction.

77. *Pressure of other stones.*—The same may be done with the topaz, enclase, arragonite, fluor spar, carbonate of lead, and rock crystal.

78. *Pressure of glass.*—Press two plates of glass together, and examine them; one will be found positively, the other negatively electrified.

79. *Pressure of metal.*——M. Libes fixed an insulating handle to a metal disc, and pressed it, holding it by the handle against a piece of gummed taffeta; the taffeta acquired positive electricity, and the metal disc negative. The effect increases with the pressure, but it ceases altogether as soon as the taffeta loses its glutinosity, which renders it easily compressible.

80. *Pressure of cork.*—Take two discs; one of cork, the other of caoutchouc. After pressing them together the cork will be positive, the caoutchouc negative.

81. When cork is pressed against the skin of an orange it becomes positive, and the orange skin negative.

82. Cork pressed against Iceland spar, sulphate of lime, sulphate of barytes, or fluor spar, becomes negative, while with cyanite, pit coal, amber, copper, zinc, and silver, it becomes positive, and the substance pressed against it of the contrary character.

83. Insulated cork pressed against any part of the animal body, provided it be not moist, receives an access of negative electricity.

Note.—It is not necessary that the bodies pressed against each other should be of contrary natures. When two discs composed of the same materials, as skin, amadou, &c. are pressed against each other, they upon separation exhibit different states, as indeed might be expected from the analogous experiments of the ribbons, *Ex.* 52. It is often however necessary to heat one of the two similar bodies to render the effect more apparent. The greatest effect is seen when one of the substances is of an elastic nature. The better conductors they are, the more rapidly the bodies pressed together should be separated.

84. *Electricity affected by heat.*—Take a piece of well dried cork, and cut it in two, by means of a very sharp knife, and then press the two cut surfaces against each other; it frequently happens, that however hard the pressure may be, and however rapidly we separate the two surfaces, neither exhibits any signs of electricity after the parting. But if we slightly heat one of the pieces of cork, by holding it near the flame of a candle, and renew the pressure, we shall find each surface possessed of a different kind of electricity.

85. *Heat and contact.*—Take two pieces of Iceland spar, press them against each other; no effect will be apparent, but if you then warm one of the pieces, and renew the pressure, a very evident excitation will be apparent.

86. *Contact of metals.*—When zinc is brought into contact with copper or silver, and again separated by means of an insulating handle, the zinc is found positive, and the copper or silver negative. The experiment is to be done thus:—Procure two circular plates, about 4 inches diameter, the one of copper, and the other of zinc, perfectly clean and bright. Let an insulating handle be screwed into the centre of each plate; hold the plates by their insulating handles, and apply their flat surfaces together, suffering them to remain in contact about a second; then separate them, and touch the insulated plate of the condenser with the copper. Bring the zinc and copper in contact with each other again; then touch the condenser as before with the copper—repeat the operation till signs of electricity are apparent by the divergence of the gold leaves. This ex-

periment requires very great care, and even with that will sometimes scarcely be satisfactory in the result. If iron or manganese, or even plumbago, be substituted for the zinc plate, the result is the same; but if gold or platinum are employed no electrical action takes place, from which M. de Rive inferred that these and similar effects resulted from chemical action, and not pressure or contact; in this case the experiment, and others which follow, belong to galvanism, and not free electricity. It is still a disputed point with philosophers. We shall presently show that they really belong to the part of the science we are now considering.

87. *Contact of powders.*—Have a tin, zinc, or copper disc, 3 inches over, with an insulating handle. Spread out upon a smooth sheet of white paper any of the following substances, quite dry; succinic, citric, oxalic, benzoic or boracic acid, sulphur, silex, alumine, carbonate of ammonia or resin. Touch the powder with the plate of metal, and apply the latter to the electrometer, when after several contacts electrical signs will be apparent; the copper being in every instance positive. With the following powders it is negative, the alkalies and their carbonates, the earths, except silex and alumine.

This and similar experiments show the near approach of those two divisions of science, distinguished as electrical and galvanic; the latter being always attended, if not caused, by some chemical change, the former being as far as we have hitherto been able to detect in cases of a similar character to this; namely, when two dissimilar metals being operated upon at the same time are accompanied by any such alteration of properties. Yet we find in other cases that electrical and chemical effects are concomitant, but these are in circumstances totally different from that of the mere contact of the bodies which we are now considering. In a galvanic circuit of metals moisture is necessary for full effect; in an electrical circuit they, and every other part of the apparatus, should be perfectly dry; we may also observe the following essential differences.

In electrical experiments we see attraction and repulsion take place between the bodies excited; in galvanism there is nothing of the kind apparent. Electricity has very little effect in causing chemical decomposition—galvanism does this by the simplest combinations. The strongest power of electricity has little effect upon a magnet, or to form one, whereas galvanism is immediately shown in its extraordinary connexion with magnetism. Thus clear distinctions between the two sciences, or two divisions of the science, are at once apparent, and serve as criteria to arrange doubtful experiments, such as those which follow.

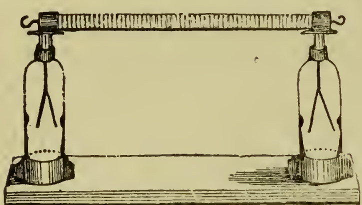
This being premised, the explanation of the following very curious instruments will be easily understood, from what has been said of the condenser and doubler. Suppose two dissimilar metals, as copper and zinc, are placed in contact with each other, electricity is excited; one metal becomes positive, the other negative—the copper will be negative, the zinc positive. Suppose we place three pairs of such metals, the three pairs having their copper sides in the same direction; each copper in connexion with its zinc, but the respective pairs varnished on the outside. Each pair becomes excited by the mere contact, and when they approach each other induction takes place, as we explained in describing the condenser, and the pairs act upon each other by mutual approach. The varnish prevents their coming into actual contact, and therefore the effect is not dissipated, from the varnish being a non-conductor. The effect of each pair is very minute, but when the pairs of plates are multiplied to 1000 or more, the result becomes powerful and decided. These views induced De Luc to contrive an apparatus, which he called his *dry pile*, the effects of which are to a very great extent proportionate to the number of plates, or rather pairs of plates. The best account of this, and two or three similar instruments, is given by Mr. Singer, who himself made many experiments with dry piles of different extent and materials. These we will describe in Mr. Singer's own words.

DRY PILE OR ELECTRIC COLUMN.

Mr. Singer says, " The materials I prefer for these piles are thin plates of flatted zinc, alternating with writing or smooth cartridge paper, and silver leaf. The silver leaf is first laid on paper, so as to form silvered paper, which is afterwards cut into small round plates by means of a hollow punch. In the same way an equal number of plates are cut from thin flatted zinc, and from common writing or cartridge paper. These plates are then arranged in the order of zinc, paper, silvered paper with the silver side upwards; zinc upon this silver, then paper, and again silvered paper with the silvered side upwards; and so on—the silver being in contact with zinc throughout, and each pair of zinc and silvered plates separated from the next pair by two discs of paper. An extensive arrangement of this kind may be placed between three thin glass rods, covered with sealing wax, and secured in a triangle, by being cemented at each end into three equidistant holes in a round piece of wood, or the plates may be introduced into a glass tube, previously well dried, and having its end covered with sealing wax, and capped with brass; one of the brass caps may be

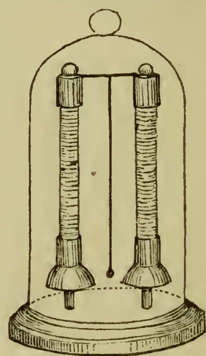
cemented on before the plates are introduced into the tube, and the other afterwards; each cap should have a screw pass through its centre, which terminates in a hook outside." This screw serves to press the plates closer together, and to secure a perfect metallic contact with the extremities of the column. The instrument constructed in this way is shown beneath :—

Ex. 88. If a column of about 1000 series is placed horizontally, with each of its extremities resting on a gold leaf electroscope, as shown in the cut, the electroscopes will each diverge; that connected with the zinc extremity of the column will be positive, that connected with the upper or silver extremity will be negative. If the column be very powerful, the gold leaves of the electroscopes will alternately strike the sides of the glass, but this motion is soon stopped by their sticking to it.



THE PERPETUAL CHIME.

Soon after the invention of the column, Mr. B. M. Foster discovered that when a sufficiently-extensive series was put together, its electric power was sufficient to produce a sort of chime, by the motion of a small brass ball between two balls, insulated and connected with the opposite extremities of the column. He constructed a series of 1500 pairs, and by its agency kept a little bell-ringing apparatus in constant activity for a considerable length of time. Mr. Singer continues : " I formed a series of from 12 to 1600 groups, which are arranged in two columns of equal length, which are separately insulated in a vertical position ; the positive end of one column is placed lowest, and the negative end of the other—their upper extremities being connected by a wire they may be considered as one continuous column. A small bell is situated between each extremity of the column and its insulating support; a brass ball is suspended by a thin thread of raw silk, so as to hang midway between the bells, and at a very small distance from each of them. For this purpose the b connected, during the adjustment of the pendulum, by a wire, that their attraction may not interfere with it; and when this wire is removed, the motion of the pendulum commences. The whole apparatus is placed upon a circular mahogany base, in which a groove is turned to receive the lower edge of a glass shade, with which the whole is covered." An instrument of this kind it is supposed will go for ever ; we have had one which has gone for many months, and a friend of ours had one of 1200 pairs of plates, which had been going three years when we saw it.

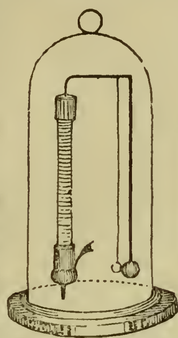


Mr. Singer directs, that in order to preserve the power of the column, the two ends should never be connected by a conducting substance for any length of time. It is therefore necessary, when laid by, that it should be placed upon two sticks of sealing wax, and that the terminal balls be ½ an inch or so from the table. And if a column which appears to have lost its power be thus insulated for a few days it will recover. There is another cause of deterioration, which is more fatal ; this is too much moisture—the paper discs therefore should be made as hot as possible before they are put together, or even subjected to a continued but gentle heat for some time before they are inclosed in the glass tube, and that being heated also the plates may be inclosed without the presence of any appreciable quantity of moisture. The size of the plates may be ⅝ of an inch in diameter, or less. With a column of 20,000 plates, a Leyden jar may be slightly charged, and minute sparks seen between a wire brought from the upper end, when it is made to approach the lower end.

DE LUC'S ÆRIAL ELECTROSCOPE.

A name given to an instrument of the same description as Mr. Singer's, intended to mark the number of oscillations made in a given time. For this purpose a single column of from 1 to 2000 series may be supported vertically

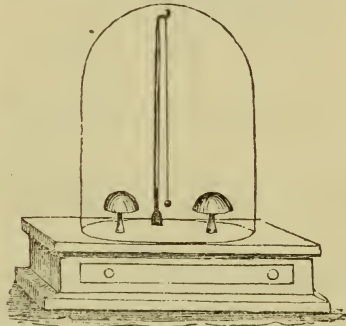
on an insulating pillar. A bent wire with a ball at its lower end, is to be connected with the upper extremity of the column, so as to hang parallel with, and be at some distance from it; the ball at its lower extremity being diametrically opposite to a similar ball that is screwed into the lower cap of the column. To the same cap is also screwed a brass fork, with a fine silver wire stretched between its extremities; this is placed above the ball, and projects beyond the



brass ball of the column, so that when the pendulum moves towards the ball it strikes this wire first, and receives a kind of jerk which prevents it from sticking. The pendulum consists of a gilt pith ball, suspended by a very fine silver wire, which hangs parallel to the bent brass wire, to which it is fastened at top. The arrangement is such, that the gilt pith ball would be always in contact with the brass ball that proceeds from the upper extremity of the column, if the apparatus had no electrical power, it therefore always returns to this situation; when, after being attracted to the lower extremity of the column, it discharges its electricity by striking against the cross silver wire.

STURGEON'S PERPETUAL MOTION.

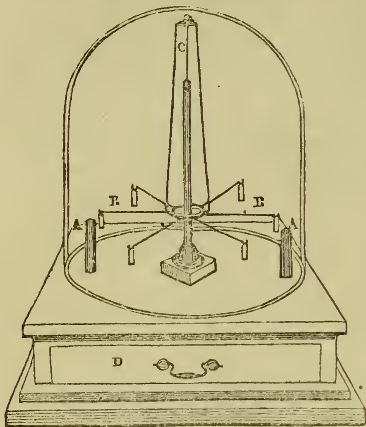
We believe this has never been described, but we remember that some years ago, Mr. Sturgeon showed us an instrument similar in its nature to the above of Mr. Singer's, but of *one* metal only. He procured a common box, about 6 inches square, and an inch deep; this was to hold the pile or collection of metals. He used two kinds of zinc, one made rough by dipping it into very dilute sulphuric or nitric acid, or scouring it with sand and water; the other made as smooth as possible. These metals were very thin, and being dried, were cut into pieces with scissars roughly into squares about ¾ of an inch on the side; they were then arranged in rows in the box thus:—First, a piece of smooth zinc, then one of rough zinc, then three pieces of writing paper made hot in the fire; again smooth zinc, rough zinc, and three pieces of paper, keeping the same order till the pile was completed. There were several rows which were laid backwards and forwards along the box, the sides of the rows not being allowed to touch each other, but their ends being rightly united with a piece of zinc reaching from one row to another. The two extreme ends had connected with them an upright piece of brass, and a pendulum so supported on a wooden or metal stem, that it played from one to the other. We write from recollection, when we give 1600 as the number of the pairs of plates. The following shows an instrument of this kind. We have made the poles to end in bells, and covered the whole with a glass shade, which appendage is necessary for all these instruments, the currents of air having a great effect in disturbing or even stopping their motion.



ZAMBONI'S PERPETUAL MOTION.

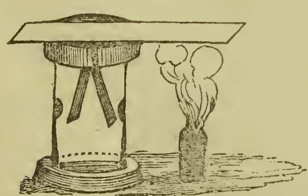
This is an instrument of the same kind as the last, or as that of Singer. The only difference consisting in the form of the instrument, and the material of the small plates. It is represented thus:—D is a box, containing a drawer; on the centre of the top of the box is a glass pillar, with a steel point at top, C. Upon this rests a very light frame-work of wire or wood, with six arms at the lower part, upon each of which is suspended a small strip of thin sheet brass or gold. The drawer is filled with several rows of pieces of paper, about an inch square each, altogether about 20,000 in number; one side of the paper is covered with silver leaf, the other painted over with black oxyde of manganese, honey, and water. The papers are arranged so that they should form one continued series throughout. Pieces of tin-foil unite the rows together. One end of this pile is connected with the pole or brass stud, A; the other with the contrary pole, A. The strips of metal hanging from the cross arms, B B, strike one pole, and then proceed to the other to deposit the electric fluid they acquired by the first impulse. So in the rotation the several strips are in like manner affected, and the frame with its various arms is in continued motion, which it will maintain for years. It is necessary that it should be covered with a glass shade, to prevent the disturbance of wind, &c. These machines

often require to be set going with the finger in the first instance, or by turning the glass shade round to produce a slight current.



EXCITATION BY CHEMICAL ACTION.

Ex. 89. *Excitation of burning charcoal.*—Charcoal, when burnt, sometimes gives out electricity; at other times none at all. It may be tried as follows:—Support a brass plate upon the top of a delicate gold leaf electroscope; then take a cylindrical piece of charcoal, with flat ends, 2 inches high and 1 inch in diameter. Place this piece of charcoal vertically, 2 inches and ½, or 3 inches below the brass plate. The charcoal communicates with the ground, and is to be lighted at the centre of the upper end, taking care that the fire does not reach the sides. A current of carbonic acid rises, and strikes against the plate, and in a few minutes the electroscope will show signs of disturbance. If the piece of charcoal be so inclined that the carbonic acid is obliged to slide up the sides of the charcoal no effect is produced; this is a very delicate experiment, and may require the aid of the condenser. The following shows the arrangement of the apparatus:—



90. *Electricity of burning hydrogen.*—The flame of hydrogen gives, at different times, very different indications of electric properties, but it may be made pretty steady in its effects upon the electrometer by the following method of Pouillet:—The hydrogen gas is made to flow out of a vertical glass tube, the flame itself having a breadth of 4 or 5 lines, and a height of about 3 inches. A coil of platinum wire is employed to conduct the electricity from the flame to the condenser. When this coil is so much larger than the flame, as to inclose it, and to be distant from its external surface about 4 inches, signs of positive electricity make their appearance. These signs become more and more intense as the distance diminishes, but when the coil becomes so small as to touch the flame, the electrical signs become weak and uncertain. Thus it appears that round the flame of hydrogen there is a sort of atmosphere, at least 4 inches in thickness, which is always charged with positive electricity.

91. If a very small coil of platinum wire be placed in the centre of the flame, in such a manner that it is enveloped on all sides, and made to communicate with the condenser, that instrument becomes immediately charged with negative electricity. Thus it appears that the outside of the flame of hydrogen is always charged with positive electricity, and the inside with negative electricity. It follows from this that there is a layer of the flame where the electricity is insensible, accordingly if we regulate the coil in such a manner that it penetrates nearly one-half into the brighter part of the flame all electrical indications disappear.—*Thompson.* Similar experiments may be tried with the flame of alcohol, ether, wax, oils, fat and vegetable bodies.

92. In a strong phial put a mixture of oxygen and hydrogen gases, in the proportion of 1 volume of the former to 2 of the latter; immerse in this quickly a slip of platinum, fastened to the inside of a good cork which fits the phial, holding the neck of the phial downwards, while inserting the platinum, and which should be made very bright previously by immersion in sulphuric acid, the action of the platinum will be such, that the gases will combine and form water, sometimes with so much force, that their union will be attended with an explosion, the platinum becoming red hot. This is an experiment of Dr. Faraday. The same had been observed before by Dobereiner, as to spongy or black platinum, and is the only way in which to account for the action of his lamp, in which a stream of hydrogen thrown upon spongy platinum heats this latter sufficiently to inflame the gas. The platinum acts as a medium to combine the hydrogen with the oxygen of the air.

EXCITATION BY CHANGE OF TEMPERATURE.

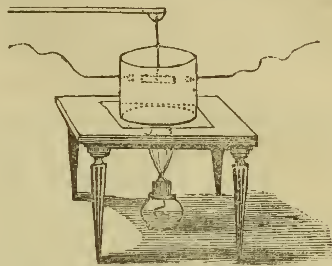
This division of the subject forms what is commonly called *thermo-electricity*, which involves so many considerations distinct from free electricity, that we cannot extend the subject beyond the mere circumstances attendant upon the electricity of the tourmalin, and one or two other bodies. The tourmalin was early known to exhibit attraction to light bodies when warmed, and the early electricians have recorded numerous appearances, which this mineral exhibited when heated. The most interesting of these are as follows, previously observing that those tourmalins only, whose ends are dissimilar to each other, can be excited so as to show in a plain manner the contrary effects of the two ends. Black tourmalins seldom have electric properties. There are two modes of exciting this stone, namely *slow* and *rapid* heating and cooling, and exceeding small alteration of temperature is sufficient to render it electric.

Ex. 93. Let a tourmalin be equally heated over all the surface, as for example, by dipping it into boiling water; then hold it to an electroscope, when the gold leaves will immediately diverge, one end exhibiting negative, the other positive electricity, and will so continue all the time of cooling.

94. Heat only one end of the tourmalin, while the other is not altered in temperature, one end will then exhibit electricity, while the other will show no effect. To try this, it may be previously fastened to a small stick of sealing wax. This is a very singular experiment, because it is an instance of one kind of electricity being apparent without the other.

95. Suspend a long crystal of tourmalin upon a stick of wax. Heat one end and cool the other at the same time, by touching one end with a piece of hot metal, and the other with a piece of ice; removing these heating and cooling objects both ends of the tourmalin will be found electrical.

96. To show these effects, M. Becquerel employed the following apparatus, which however is by no means necessary. The tourmalin is placed in a slip of paper, suspended horizontally within a glass cylinder, by means of a single thread of raw silk; this cylinder reposes upon a metal plate, which is heated by means of a spirit lamp beneath it. In proportion as the inside of the cylinder becomes heated, the tourmalin becomes electric, in consequence of the elevation of its temperature. If it now be drawn up, as shown in the figure, until it is of the height of two minute balls and wires connected with two gold leaf electroscopes, upon applying the ends of the heated tourmalin to each of these alternately, both will be charged, one with negative, and the other with positive electricity.



Ex. 97. Put a heated tourmalin on the cap of an electroscope, and then let it cool. The gold leaves will diverge, and if the upper surface be connected by a bit of tin foil, or a wire, with the cap of a second electroscope, that also will diverge, with electricity of a contrary character, as may be proved by bringing them together, when the electricity of the one will destroy that of the other.

98. The electricity of each side, or of both, may be reversed by heating or cooling in contact with various substances, so if it is cooled or heated in contact with the palm of the hand, that side of it, which would have been positive if cooled in the open air is now negative, and that which is now positive would have been negative.

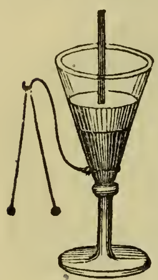
Most of the above properties have been also observed of other stones, particularly of boracite, axinite, mesotype, the silicate of zinc, tapaz, sphene, calcareous spar, amethyst, diamond, red and blue fluor spar, garnet, and many other bodies, though it appears probable that it is only in those crystals which are irregular that such appearances can be noticed. In the melting and cooling of sulphur there are several analogous phenomena; the nature of electricity depending upon the nature of the vessel in which the experiments are conducted.

99. The following experiment on the electricity of heat is one of Mr. Canton. He procured some thin glass balls, of about an inch, and an inch and ½ in diameter, with stems or tubes about 8 or 9 inches in length, and electrified them, some positively on the outside, others negatively, and then sealed them hermetically; soon after he applied the naked balls to his electrometer, and could not observe the least sign of their being electrical; but holding them at the fire, at the distance of 5 or 6 inches, they became strongly electrical in a short time, and more so when they were cooling. These balls would every time they were heated give the electric power to, or take it from other bodies, ac-

cording to the plus or minus state of it within them. Heating them frequently, diminished their power, but keeping one of them under water for a week, did not in the least impair it. The balls retained their virtues above six years. We have not tried this experiment.

THE SULPHUR CONE.

The apparatus by which this experiment is done is made as follows:—Take a large tapering wine glass, cover a portion of the outside tapering part with tin foil; twist a wire, as represented, and upon the end of it suspend two fine pith balls by *linen* threads. Having ready some melted sulphur, and a thin glass rod, pour the suphur into the glass, and immerse the glass rod into the upper part as a handle; hold it there till congealed, then suffer it to harden of itself—when quite cold the apparatus is complete. You must, however, be very particular that a chain, wire, or some other conducting substance, connects the wire with the ground during the cooling of the sulphur, or no effect will be produced—that is if it has been melted in a pipkin.



Ex. 100. Lift up by the glass handle, the sulphur within the conical glass, and at the the moment of separation, the pith balls will diverge, or separate from each other. Let the sulphur drop down again into the glass, and this action of the balls will cease. Again produce separation of contact, and they will again diverge; and thus, for a considerable time, the alternate action will be kept up, even indeed for days and weeks.

101. Melt some sulphur in an earthen vessel, put it in a melted state to cool upon a piece of metal; it will upon separation be found highly electrical, as may be proved by holding it to an electroscope.

102. Pour some melted sulphur, which has been heated in an earthen vessel, upon a piece of smooth glass. Upon separation of the sulphur, when cold, no electric appearances are perceptible.

103. Let sulphur be melted in a glass vessel, and afterwards left to cool, they will both acquire a strong electricity. The sulphur negative, and the glass positive, whether they be left to cool upon conductors or not.

104. Let melted sulphur be poured into a cup of baked wood, it acquires a negative, and the wood a positive electricity; but if it be poured into sulphur, or rough glass, it acquires no sensible electricity.

EXCITATION BY CLEAVAGE

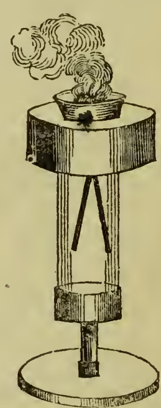
Ex. 105. Take a piece of dry talc, warm it, then split it rapidly; hold one of the pieces to the electroscope, the effect is here very strong; if the talc be split rapidly in the dark, a faint phosphorescent light will appear between the sides of it.

106. If we fix with mastic or shell lac an insulating handle upon each of the faces of a plate of mica, we may ascertain that each of the slices separated is in a contrary state of electricity; the intensity of which increases with the rapidity of the separation. Before making these experiments we must well dry the talc, and observe that it is not already split.

107. Make a large card warm at the fire, double it across, and tear it in half; at the part doubled each fragment will become electrical, and the one in a contrary state to the other.

EXCITATION BY EVAPORATION.

Ex. 108. Place upon the cap of a gold leaf electroscope, a small tin dish or patty pan, having in it a red hot coal just taken out of the fire. Sprinkle upon the coal a few drops of water—the evaporation of this will set the gold leaves into considerable action. This will not succeed with either charcoal or coke. It does best with a hot iron put into the water.



Volta, Lavoisier, La Place, and others, state that water never changes its condition, without electric effects being produced. Others contend that this is not the case, unless chemical change also accompanies the action. The electricity of steam, a recent discovery, and which we must defer the consideration of for some chapters, will throw much light upon this subject.

CHAP. III.

ELECTRICS AND CONDUCTORS. ELECTROPHORUS. CAUSE OF ELECTRICAL APPEARANCE.

The only experiments on electricity known to the ancients, were, as before observed, the attractive powers of amber when rubbed; and the very first set of electrical experiments tried by the moderns was to discover if any, and what substances possessed the same extraordinary properties. These experiments, and which were made by Dr. Gilbert early in the seventeenth century, were the foundation of the science of electricity, as they directed the attention of philosophers to the subject. Considering how universal a fluid it is, and how easily excited, it must be a matter of surprise, that the discoveries of Dr. Gilbert had not been some of them made long previously. In trying to elicit electric properties from various bodies, this physician was successful only in certain cases, particularly in electrizing some stony materials; and nearly a century passed before Dr. Grey, Desaguliers, and others, renewed the subject with that energy which might have been expected. The former of these gentlemen discovered that electricity might be communicated to, and would pass along certain bodies, as for example, that it would pass along hemp, but not along silk. Thus, that bodies were not possessed of the same characters was evident. It was afterwards found that those bodies which could be excited by the ordinary means then employed would not convey or conduct the fluid readily along them, and, on the contrary, those which conducted the fluid, could not be excited. Hence arose the two terms *electrics* and *conductors*. Both these terms are still retained in their original sense, but the former of them is to be understood to include only those bodies which show electric properties in ordinary circumstances when held in the hand, and which do not require to be *insulated* previous to excitation; for it will have been observed in many of the preceding experiments, that conductors, as for example the metals, may, by taking proper means, be no less excited than other bodies, as was shown in *Ex.* 86, 79, and 32, and which the next experiments will exhibit still more plainly. So that the term electric is not quite accurate, although retained for the sake of convenience. These electrical bodies are often called *non-conductors*, a term better in some respects than electrics, though not in others, as we shall see that a body may be a conductor in one condition, and a non-conductor in another.

It will be seen from the above, that a particular substance may be an electric in one state, and a conductor in another; thus glass and sulphur are both excellent electrics when in masses, but when pulverized become imperfect conductors. So green wood is a conductor; baked wood a non-conductor; baked still more into charcoal a conductor again; and when in the state of wood ashes a non-conductor once more. Many bodies also are conductors merely because they contain water; thus almost all highly-dried animal and vegetable matters are non-conducting. Dried glue, parchment, bone, ivory, hair, feathers, horn, tortoise-shell, wool, silk, gums, resins, wax, cotton, sugar, &c., &c., are electrics, yet as soon as either of them becomes damp, a conducting property is communicated; hence the necessity of well drying electrical apparatus when in use; and also the same fact shows the reason that machines of this kind act so imperfectly in damp weather, or in a room before a crowded audience, whose breath quickly settles in moisture upon the

various electrics around. Too great heat also impairs the insulating effect of glass, &c.; for although it will not in ordinary temperatures suffer the fluid to pass along its surface, yet when heated to redness it becomes a good conductor; and so also is baked wood made very hot, melted resin, hot air, &c.

Notwithstanding this, we for convenience sake divide all bodies into the two classes of *conductors* and *non-conductors*, or *electrics* and *non-electrics*. the former parting immediately with any fluid given to them, and the latter retaining it so as to be apparent to the senses. Thus air is an electric or non-conductor—were it not so, electrical experiments would be unknown, the fluid being dissipated as fast as it is accumulated; water, on the contrary, is a good conductor, hence the necessity of keeping the apparatus dry, that the disturbed fluid may be retained. Metals are the best conductors, therefore we use them for such parts of our electrical machines as are intended for the transit of the accumulated fluid. Glass and silk are electrics, or non-conductors, consequently are available as bodies to be excited, and as capable of preventing its escape and dispersion. Thus of an electrical machine the connexion between the cushion and the earth is a metallic chain or wire, to allow of the passage upwards of electricity, the glass cylinder being rubbed sets it free, the brass or tin conductor collects it, and its glass support *insulates* it, and thus prevents its escape to the earth again.

The following experiments show that metals may be excited equally with those bodies ordinarily called electrics.

Ex. 109. *Electricity of quicksilver.*—Inclose some quicksilver in a thin glass tube a foot long, and of an inch in diameter. Make the tube dry, cork it up, and shake the quicksilver briskly from end to end. If now the tube be held towards any electrometer or electroscope, it will show itself powerfully excited.

110. Put a small cup upon the gold leaf electroscope, and pour the quicksilver from the tube into the cup, when the divergence of the leaves will show the metal to be excited. It may be considered doubtful if the metal be here excited at all, or whether it be not the glass alone excited, and have communicated its electricity to the metal, but let it be remembered, that when two bodies are rubbed together, they are both excited at the same time, but in a contrary degree.

111. Let the two electroscopes, which were used in the last experiment, one of which was charged by the metal, the other by the glass, be touched together; the electricity of them will *not* be destroyed, because we have applied to one of them the *outside* of the glass tube, whereas it was the inside that was subjected to friction. The inside therefore is in a contrary state to that of the metal, and the outside in the same state as the metal. The metal is negative—the inner side of the glass positive, the outer side negative, as may be tested in the usual way.

112. *Luminous barometer.*—Let the tube which holds the mercury be exhausted of air, and then shaken briskly up and down the tube; flashes of light will dart across the tube. This, which is an experiment of Mr. Hawksbee, may be done in a flask or large phial, and without any great degree of exhaustion; even heating the vessel well, and thereby rarifying the air, will often be sufficient.

113. Put a gold leaf electroscope under a tall open-topped receiver of an air pump. Place a small wooden mercury cup to close the top of the receiver, pour a little mercury in it, and exhaust the air beneath; as the mercury filters through the cup it will become excited, as will be seen when the drops fall upon the electroscope.

114. Place a smooth round plate of metal on a cake of rosin or shell lac, rub the metal with a cat skin; draw it up by a silk thread previously attached to it, and it will be found excited.

It will be evident that a knowledge of the individual conducting powers of all substances is requisite to a right understanding of the first principles of the science, and that even the simplest experiments may be conducted with success. The following table presents a series of conductors and electrics, beginning with those which have the greatest conducting power, and terminating with those that have the least. The order in which they possess the power of insulating is of course the reverse of this; that is to say, the best or most perfect electrics are at the

bottom of the table. It may also be observed, that the middle of the table exhibits bodies almost neutral in their properties, being but very imperfect conductors, or very slight electrics :—

The most perfect or least oxidable metals.
The most oxidable metals.
Charcoal ; especially from hard wood.
Plumbago, or black lead.
The mineral acids.
Metallic salts and ores.
Water and other liquids ; and snow.
Living vegetables and animals.
Smoke, soot, and steam.
Rarified air and flame.
Dry earths and stones.
Pulverized glass.
Flowers of sulphur.

Dry metallic oxydes.
Oils.
Vegetable and animal ashes.
Ice; when cooled down to 13° Fah.
Phosphorus.
Lime, dry chalk, and marble.
Caoutchouc, camphor, and bitumen.
Silicious and argillaceous stones.
Porcelain.
Baked wood.
Dry atmospheric air and other gases.
White sugar and sugar candy.
Dry parchment and paper.
Cotton.
Feathers, hair, and silk.
Transparent gems.
Glass.
Fat.
Wax.
Sulphur.
Resins.
Amber and gum lac.

To discover if a body be an electric or not, hold it against the conductor of a machine when charged; if a spark can now be taken by the knuckle from another part of the conductor, the substance under examination is an electric ; if not it is a conductor. If a liquid, a gas, or a powder is to be tried, inclose it in a glass tube ; should the spark not now pass it will be known to have been conveyed away by the liquid, &c. under trial.

The following experiments will illustrate the foregoing remarks, and show the methods of distinguishing the bodies which belong to these two classes.

Ex. 115. Let a metallic cylinder be placed upon silk lines, or upon dry glass ; bring an excited glass tube so as to touch it, and every part of the cylinder will attract and repel light bodies as forcibly as the excited electric itself, showing that metal is a conductor.

116. Support a dry glass rod on silken lines, bring an excited glass rod near it, and no attraction or repulsion will take place, showing that the glass rod is not a conductor.

117. If the glass rod of the last experiment be wetted with water, it will show electric signs in the same manner as the metal of *Ex.* 115, but if with oil, very slight effects will be communicated, showing water to be a good conductor, but oil a very bad one.

118. While you try the *Ex.* 115, place a lighted candle near to the metallic rod, and the fluid which would otherwise be discoverable in the metal will have been dissipated by the flame and rarified air ; they are therefore conductors ; yet it is evident, that air at its usual temperature and pressure is a non-conductor, otherwise few electrical appearances of any kind could be observed, as the air would dissipate or convey away the fluid accumulated.

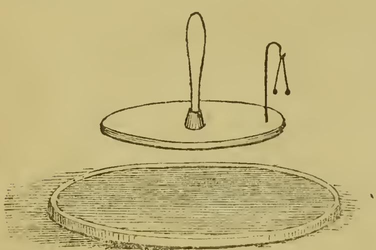
It will have been observed, that wherever we have shown friction, there has also been separation of contact ; and upon a strict examination it will be found, that although the rubbing of two dissimilar bodies together may, and does occasion the electric fluid to be disturbed, yet it is only when these bodies are held apart, that each is found to put on electrical appearances. Thus in *Ex.* 4, the brown paper is the one body, and the coat the other. In *Ex.* 7, the coffee is the one body, and the mill in which it is ground the other ; so also in *Ex.* 15. The comb passing over the hair must certainly be separated in turn from those particular parts it touches in its course along, and not till then is it seen that those parts are electrical ; and thus in every experiment there is not merely friction, but separation of the parts rubbed together, where it is not so, no electrical appearance would be perceived, as is clearly proved by *Ex.* 100, where electric effects were perceptible only when the sulphur was separated from the glass. An experiment similar to this is as follows :—

Ex. 119. Pour some melted sulphur into a metal cap which is supported upon the top of a gold leaf electroscope ; dip a glass rod in it as a handle, and let it get cold ; when quite cold, lift up the sulphur by the handle, and the gold leaves will immediately diverge, the cup itself being electrified, and if the sulphur be held to another electroscope, that will be shown also to be excited. As often as it is raised from the cup, the effects become manifest, and when put down again they cease.

120. Take a piece of glass, about 5 inches long by 3 inches broad—warm it, wrap tin foil all over it, and rub the outside of the tin foil smartly with the hand. The glass

thus excited, held to the cap of Bennett's gold leaf electroscope, will not show any electrical effect while it remains wrapped in the tin foil, but if this be removed, and the glass alone be presented, the gold leaves will instantly diverge.

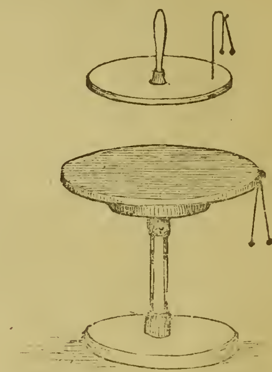
The same is exemplified in the electrophorus, an instrument which is described, and may be made as follows:—Procure a round piece of tin, about 10 inches over, and have the edge of it turned up about $\frac{1}{4}$ of an inch, so as to be capable of holding some of the following mixture; (melted over a fire,) 1 pound of yellow rosin, and 2 ounces of wax. This being poured into it, and suffered to cool, one part of the electrophorus will be complete. Next provide a round plate of wood, about $\frac{1}{2}$ an inch thick, and 6 or 7 inches over, which must have a smooth edge, and without any sharp points or angles; cover this with tin foil, and fix a glass rod to the middle of it as a handle. This may, altogether, cost 2*s*, and is a really useful electrical machine, capable of showing all the fundamental facts of the science. The following cut will render the description more evident:—



121. To excite it, warm and wipe the glass handle, and also the resinous plate. Rub this plate briskly with a warm flannel, and put the wooden plate upon it, holding it by the glass handle—touch the wooden plate for a moment with the finger, and it will be full of the fluid in a disturbed state, not, however, apparent until the wooden plate is lifted up, when a spark may be taken from it; put it down again, touch it with the finger, and lift the plate up again, (first removing the finger,) and a second spark may be taken, and so on for a considerable length of time.

122. Fasten near to the edge of the upper plate of the electrophorus a bent wire, bearing on the end of it two suspended pith balls—whenever the upper plate is removed from the lower, both being excited and touched with the finger, as above directed, the pith balls will be violently repelled from each other.

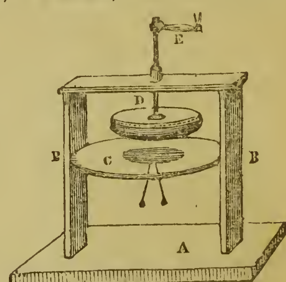
123. If the resinous plate be excited, and placed upon a glass stand, and two pith balls be suspended from the rim of it; whenever the upper plate is lifted up these balls also will diverge, showing that the lower plate also appears excited when separation of contact ensues. Many other experiments with this instrument will afterwards be shown.



Numerous experiments of the last chapter evidence the same fact, which is rendered still more conclusive by the following machine, called

THE CIRCULAR RUBBING MACHINE.

This consists of a square frame of wood B B, supported by a square foot A, having a circular rubber or cushion D, stuffed with flannel and covered with leather, which is turned by a handle at top E. This rubber rests upon a plate of glass C, about 8 inches in diameter. The under surface of the glass has pasted upon it a round piece of tin foil, 3 or 4 inches over, with two pith balls hanging by fine wires, or a thread, from the centre of it.



Ex. 124. Prepare the apparatus by warming the glass, and spreading a little amalgam on the cushion—turn round the handle, which will produce a friction, and excite the glass. In this state there will be no appearance of the fluid being disturbed, until the cushion be lifted up, when the balls

will diverge—placing it down again their motion will cease, and thus they may be alternately moved by producing and separating contact.

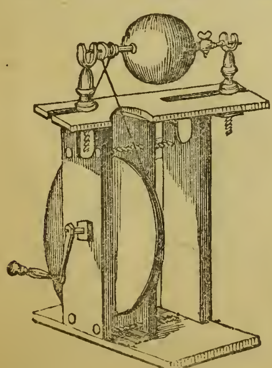
Electrical amalgam.—Melt in a ladle ½ an ounce of zinc. When melted, add and stir up with it 2 ounces of quicksilver. When cold pound it with a little wax or grease, when it will be fit for use. This substance is of value to the electrician, as being the best of all matters to excite glass with, so that in the electrical machine such is indispensable, and if we had used it, spread upon a piece of leather, in *Ex.* 6, 9, and others, instead of the old black silk handkerchief, the effect would have been much greater.

CHAP. IV.

OF THE ELECTRICAL MACHINE AND MANNER OF USING IT.

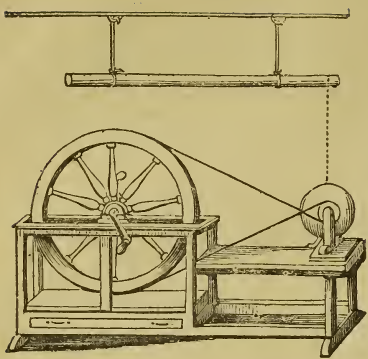
In our future experimental researches on electricity it will be necessary to use a *machine*, for the purpose of accumulating the fluid in greater quantity than the glass tube or such simple means allows, and also of retaining it in such a condensed state as to afford the powerful effects of which it is capable. From the last chapter it became evident that to excite, accumulate, retain, and transfer the electric fluid, a due knowledge of electrics and conductors was necessary;—that the capability of excitation and retention depended upon the quality of the electric, and the power of a rapid transmission of the fluid; upon the perfect conducting power of the material through or over which it was to pass. Electricians employ for the one purpose chiefly the metals, they being the best conductors; and sulphur, glass, resin, and silk as electrics, or as bodies to be excited. The proper union of these forms an electrical machine.

In the early history of the science, when attraction and repulsion only were to be observed, all that the electricians aimed at was to give the requisite friction to the electric in a more convenient manner than by the simple experiments of rubbing upon the sleeve, or with other light material. With this intention Otto Guericke fitted a globe of glass; upon an axis. Upon giving it a whirling motion, and holding his hand against it at the same time, he was enabled to excite it with great convenience. Mr. Hawkesbee's machine, and which was so similar to this, that one illustration will serve for both, was the next contrivance. It is shown in the cut.



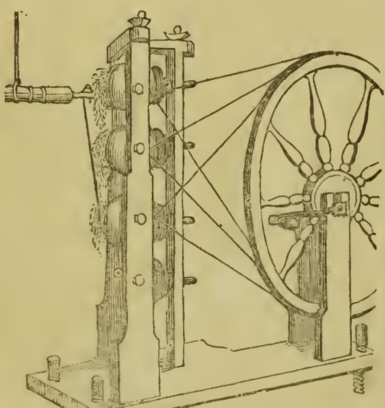
It will be seen that here is no cushion, no conductor, no means of collecting the fluid from the earth, and none to draw or collect it from the cylinder, as we shall presently show are all necessary. Therefore, although answering the purposes then required, it is very inefficient compared to our more modern inventions. Otto Guericke had no means of forming a globe of sulphur but casting it in a glass globe, and then breaking the glass from off it. Mr. Hawkesbee used the glass globe itself rather than that of sulphur, and in that was the great difference between his machine and that of Otto Guericke.

The next machine was invented by the Abbé Nollet. Of this description was the greater part of the machines which were used about one hundred years since. It is represented annexed:—

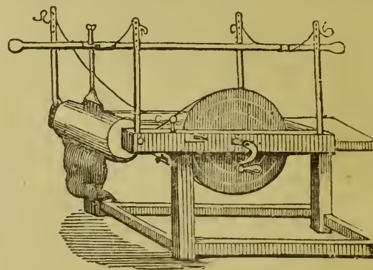


These were the machines, heavy and unwieldy as they seem, which were carried about from place to place for exhibition. The advantage of this machine over the last was its different and more convenient form, and the appendage of a conductor, which was hung by silk lines from the ceiling. The globe was still rubbed by the hand. The conductor was a bar of iron, or generally a gun barrel, connected to the electric by a chain hanging from it, and touching the revolving globe.

In the next machine constructed, four globes were whirled at once; it was a contrivance of Dr. Watson, and is represented beneath :—

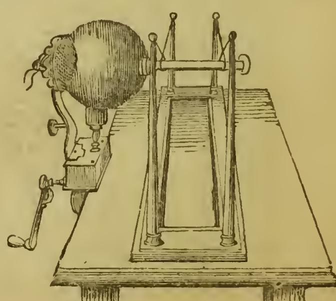


The conductor was, as before, suspended from the ceiling, and connected by the various globes by unravelled gold lace hanging down from them. As it was evident that the hand could not be held against four globes at once, a cushion was appended to each globe, and hence arose another great improvement—indeed the machine was now furnished with all its most valuable parts; a globe to be excited, a cushion to supply the fluid, and a prime conductor to collect it. Still, as will be evident, it was very large and unwieldy, and the necessity of suspending the conductor from the ceiling a great inconvenience. The improvement therefore of Mr. Wilson was particularly acceptable to the electrician. This gentleman's machine is as follows :—

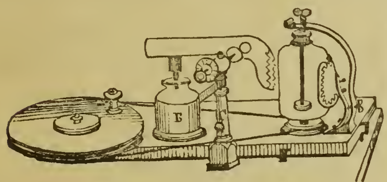


A cylinder is substituted instead of a globe; the cushion is placed beneath. This was a great improvement. The conductor was suspended on silk lines fastened to upright pillars of glass. Instead also of the uncertain method of a chain or fine wire hanging down from the conductor to the cylinder, Mr. Wilson substituted a second rod, which was terminated at the end by a row of points; another great improvement. The greatest inconvenience of this machine was the great strength required to be given to all its parts to prevent the conductor from vibrating to and fro, when the cylinder was put in motion by turning the handle.

The next machine was much more portable; it was invented by Mr. Nairne. The differences between this and the former were that the globe was turned by means of some brass wheel-work contained in a box beneath the globe, and which for the first time was made to work by a vertical motion ;—the cushion was made with a spring, to produce equality of pressure, and the conductor was in a greater degree unconnected with the globe than before. It is represented beneath :—

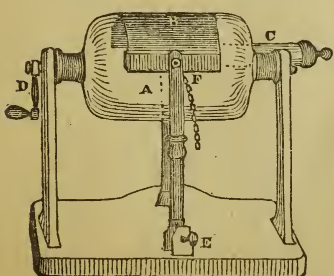


A second machine, also we believe by Mr. Nairne, has a cylinder, working vertically, with a multiplying wheel beneath, and another on the table. The conductor is made of tin, and instead of a series of points attached to it, it has the edges of the end of the prime conductor cut like teeth. This was invented about 1760, and consequently after the discovery of the Leyden jar. It was used also entirely for medical electricity, which accounts for the Leyden jar B, and also for the electrometer at the side being attached to it. These, however, are in reality no parts of the machine itself. Mr. Nairne first used amalgam to the electrical machine. This machine is represented in the following cut:—



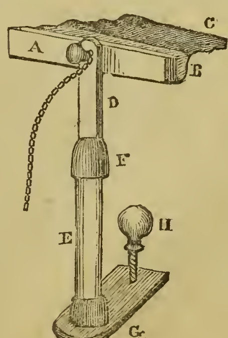
Thus in the hands of Mr. Nairne, who was a celebrated optician in Cornhill, that which was before cumbrous and comparatively ineffective, became a useful, portable, and easily-constructed instrument, rendered however yet more convenient and powerful by the horizontal position of the cylinder, and the silk flap introduced by Dr. Priestley. This was the history of what is now called the *cylinder machine*, which is shown in its modern and most approved form, as follows. Be it observed, that the cylinder machine varies in having sometimes two conductors; one attached to the cushion for negative electricity, and the other for positive electricity; this last is always present, and is called the prime conductor. It may also be turned by a common handle, or by a multiplying wheel, as found most convenient; we decidedly prefer the former, particularly for a large machine.

THE CYLINDER MACHINE.



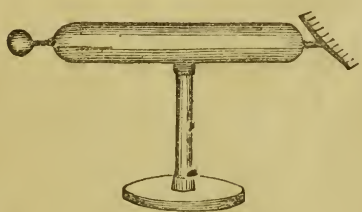
A is a glass cylinder, having upon each end of it a cap of wood or brass, and supported by a stand with two uprights. The end of one cap is turned with a pivot, which fits into a hole near the top of one of the uprights. The other cap is turned with a similar pivot, and has beyond this a flanch and a square gudgeon, upon which a handle D fits. This end of the cylinder is supported in a similar manner to the other end, but instead of a hole merely being bored in the upright leg, a portion is cut away, that the cylinder may be the more easily taken out and put up again in its place; it may be secured when there by a pin run through the upright, just above the axis of the cap. Before the cylinder is a cushion, which extends in length to within an inch of either end of the cylinder; it is from 1 to 2 inches in width, according to the size of the cylinder, and made by laying five or six folds of flannel over the wooden back of the cushion, and neatly covering these with leather. The cushion when finished should be soft, and yielding about as much as a wool mattress, and scarcely so hard as the bottom of a hair-covered chair.

On the lower part of the cushion is glued a flap of leather (the rough side outwards), and on the edge of the leather the silk flap which passes over the cylinder when in action. B, the cushion, is supported sometimes by a thick rod of glass with a wooden spring at the top of it, as in the figure; at other times a springy piece of wood alone is used. It is fastened at the top to the cushion by a hand-screw, which passes through the support, and is fixed by a thread in the back of the cushion itself. The lower end of the support for the cushion is made so as to slide backwards and forwards, either on the top, or still better underneath the stand, and is held in its position by a thumb-screw. The object of this sliding is to regulate the pressure of the cushion against the cylinder, as shown in the cut, or the cushion may be made a fix-



ture, and its pressure regulated by a screw behind it, as at the letter E, in the cut of the whole machine above given. When the cushion slides backwards and forwards, a slot or long hole is made in the foot board, and the small piece of wood which forms the foot of the cushion slides in a groove beneath the foot board. In the cut A shows the back of the cushion. B the leather flap. C the silk. D the wooden spring. E the glass support. F the cap, which unites the glass and spring. G the foot. H the holding screw. The part D is united to A by a round wooden screw on which a chain is hung when the machine is in use; this chain ought to touch the ground.

C represents the *prime conductor*, formed either of wood covered neatly with tin foil, or of metal. It has round and smooth ends, at one of them a ball and wire for the suspending of various apparatus, at the other a projecting wire furnished with a row of points to collect the fluid when disturbed by the cylinder. It is necessarily supported upon a glass pillar, sometimes attached at the lower end to the same stand as the rest of the machine, in which case the conductor runs parallel to the cylinder, and has the points driven into the side instead of the end. At other times it is fixed to a separate foot as is to be seen in the figure beneath. At the top of the conductor are two or three holes to afford greater facility in performing experiments.



To make a machine.—In making a cylinder machine observe carefully the following directions :—The centre of the cylinder, of the cushion, and of the conductor should be of the same height. The lower part of the cylinder, unless in a very small machine, should be at least 10 inches above the foot of the stand beneath. The glass pillar of the prime conductor not less than 14 inches long, the conductor itself about as long as the cylinder, and from 2 to 3 inches diameter ; the points projecting nearly an inch. The silk flap should be thin, and extend to within an inch of the points. Fix the caps upon the cylinder thus :—Make some cement, (according to the receipt in p. 8,) which have melted ready for use ; roughen with a file the glass on each end of the cylinder, and bore a small hole through the axis of that cap which does *not* bear the handle ; this done, stop up the inner end of the hole again with a small piece of dough, putty, or clay. Now grease the outside of this cap well, put it in an upright position, half fill it with the melted cement, warm well the end of the cylinder, put it upright into the prepared cap, let it remain till the cement is hard, and then clear out the hole through the centre by a hot wire ; being very careful that it is at all times afterwards left open. This is necessary as a vent for the heated air, which of course will be liable otherwise to burst the cylinder, not merely when the other cap is fixed to it, but ever afterwards when the machine is in action. The hole being thus opened, the other cap may be fixed on in the same manner ; a second hole however is not necessary. The cause of greasing the outside of the cap is that any cement which flows over may not stick to it.

By attending to the above description and observations, an electrical machine may be made out of a common sample phial, capable of giving sparks, charging a Leyden jar, and performing most of the simple electrical experiments.

To work the machine.—Warm the whole well before the fire, and cleanse it from all damp and dust. Take off the cushion, scrape away all dirt, spread evenly upon it some fresh amalgam, (a receipt for which see page 27 ;) put it back in its proper place, and fasten to the screw which connects it with its upright a brass chain, the other end of which reaches to the table or floor, or the walls of the apartment. Upon now turning the handle, streams of fluid will be seen to issue from the cushion, and passing under the silk to fly off at its edges. To collect the fluid, place the conductor with its points about a quarter of an inch from the edge of the silk, which will so readily attract the fluid from the cylinder that sparks proportionate to the extent of the glass surface rubbed may be taken from it, being very careful however that the glass stand of the conductor be perfectly dry. The pressure of the cushion against the cylinder is to be regulated by the screw on the stand at bottom.

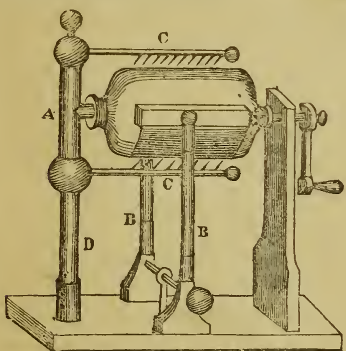
Note.—If the machine be small it will require frequent warming ; the power of a machine is generally increased by rubbing the cylinder for a minute or two with a slightly-greased rag, or by putting one hand upon the cushion.

The rationale of the action going on is this :—The fluid passes from the earth through means of the floor, walls, &c., to the chain suspended from the cushion ; here friction, which is the cause of the disturbance, takes place. The disturbed fluid passes to the

glass cylinder, and is confined from escape by the silk flap; that ceasing, the fluid would fly to anything around, particularly to a pointed body, or a lighted candle; but this is prevented by the superior attraction for it from the nearer end of the prime conductor put to receive it. Thus it will be at once seen that an electrical machine resembles a pump; the earth may be likened to a well of water; the chain to the lower pipe of a pump; the cushion is the sucker; the silk the nozzle; and the prime conductor is like a pail to hold the fluid.

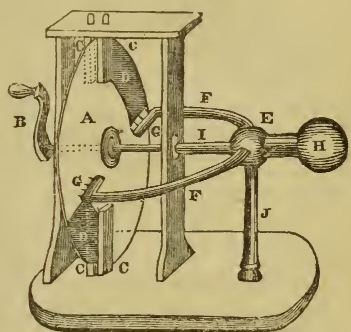
PALMER'S CYLINDER MACHINE.

Mr. Palmer, an optician of Newgate Street, has so far modified the cylinder machine as to adapt two cushions and two prime conductors to it, as will be readily understood by the following figure and short description:—A is a thick glass tube, having a ball at the top, and two arms, projecting sideways, furnished with points as C C. The tube A supports one end of the cylinder, and is itself supported upon a solid glass pillar D. B B are glass pillars, which support the cushions and flaps.



CUTHBERTSON'S PLATE MACHINE.

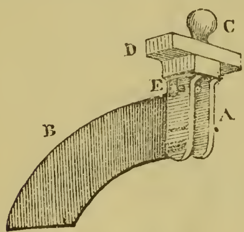
This machine is undoubtedly superior to the cylinder machine, both in power and degree of portability; but it cannot be so readily made by an amateur, and it is attended by a great defect, namely, that the plate of glass which forms the electric to be rubbed is very apt to become starred or cracked from the centre outwards. This takes place from two causes; one, unequal pressure of the cushion, and still more frequently from the following want of care. Previous to an electrical machine being worked it is usual to place it near the fire to become dry, and in a slight degree warm. Now it is evident from the shape of the plate machine, that the *side* of the plate would be placed, nine times out of ten, towards the fire, and of course the opposite side exposed towards the door of the room or window. The side nearest the fire becoming warm is expanded, while the other side, glass (being a bad conductor of heat,) will remain as at first; the glass plate is therefore distorted, and if the door be opened by a person entering, a sudden contraction takes place in the nearer side, which, added to the expansion of the other, cracks the glass at its point of support, or fulcrum, which is the centre. Again, if when the glass plate is unequally heated, the cushions be put on tightly, and the handle be then turned, fracture is almost certain. With these drawbacks upon its utility the plate machine is still better than the cylinder, especially for lecturing before a large audience, as it is less liable to be affected by the moisture of the apartment, arising from breath and other causes. It is figured and described as follows:—



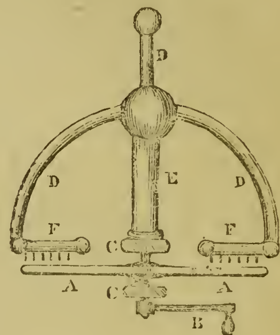
A is the plate of glass, which is made circular, and has a hole drilled through the centre for the admission of a spindle, so that it may be turned by the handle B. C C C C are four cushions, fixed two and two together to rub against the glass. D D are two double flaps of black silk. E is the prime conductor, which is of metal, terminated by a ball H at one end, and after branching into two arms F F, which are bent at the part next the plate, terminating with points as at G G. I and J are glass rods to support the prime conductor. These are not both necessary if the machine be small; the rod marked I will then be sufficient. The structure of the cushions and the prime conductor is seen in the annexed cuts.

A represents two cushions, or rather two vertical pieces of wood, on the inner side of which two cushions are to be placed. The cushions merely fitting in a groove or hole, or else attached on a projecting pin or two, that they may be taken off and put on again readily on putting the machine in order. The cushion and also these pieces may be

about an inch wide, and of such a length as to leave 4 or 5 inches between their inner extremities and the brass flanch of the central axis of the plate. The pieces A, or cushions, may also take off by unscrewing the hand screw at the top, marked C, which passes through the top frame of the machine D. E is a screw to regulate the pressure of the cushion upon the plate. B represents the silk flaps; there being one to each side of A. These are sewed together around the outer edge, so that the plate revolves between them. Any common silk of a black color will answer for this purpose, and it is quite immaterial if it be previously oiled or not.



The annexed figure shows the prime conductor, as separated from the machine, or rather a vertical representation of the whole machine, except the stand and cushions. A A is the plate of glass. B the handle. C C the supports. D D D the prime conductor, all of brass. E its horizontal glass support. F F bent metallic arms, with points to collect the fluid from the glass.



Other machines have been invented, o more or less utility, but all these merge intc the foregoing, and are therefore easily understood.

CHAP. V.

ELECTRICAL ATTRACTION, REPULSION, INDUCTION, AND DISTRIBUTION.

We have already said so much about electrical attraction and repulsion, that we have nov but little to add, more than to illustrate the subject by those more showy experiments whicl the greater power we have obtained by means of the electrical machine enable us to exhibit and to explain the laws which seem to regulate the degree and continuance of those effect: Bearing then in mind the theory of Franklin, that a body may be charged *positively* o *negatively*, and that the electric fluid is repellant of itself, but attractive of all othe matter, we shall be able to establish these laws.

1. Bodies that are electrified positively repel each other.
2. Bodies that are electrified negatively repel each other.
3. Bodies electrified by contrary powers attract each other.
4. Those substances that are brought within the influence of electrified bodies becom possessed of a contrary electricity, or electrified substances, without parting with their ow electricity act upon other bodies in their own neighbourhood; producing in them a electricity which is contrary to their own, or bodies which are immerged in an electri atmosphere, always become possessed of an electricity contrary to that of the body in whose atmosphere they are immerged.

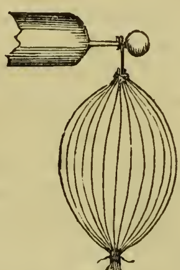
5. That the degree of attraction or repulsion is inversely proportionate to the square of the distance of the electric body and that it acts upon; that is, if an unelectrified body be offered to another which is electrified, consecutively at the three several distances of 1 inch, 2 inches, and 4 inches, as the squares of these numbers are 1, 4, and 16, we have only to invert these, and we shall find that if at 1 inch distance, the attractive force be 16, at 2 inches it would be as 4, and at 4 inches as 1 only; or, in other words, if the attractive force at 1 inch be as 1, at 2 inches it would be as $\frac{1}{4}$, at 3 inches $\frac{1}{9}$, and at 4 inches as $\frac{1}{16}$, and so on for higher numbers.

This fifth law, although important in proving the niceties of the science, and in showing that the laws of other sciences or powers of nature are accordant to those of electricity, yet as its full exposition will yield no experiments of a popular character, we will pass it over with the mere description of the method by which it is proved. It was ascertained by Mr. Canton, that an electrified body communicates its own electricity to all the particles of air which come in contact with it. These particles are immediately repelled, and their place supplied by a new set of aerial particles. The consequence of this must be, that the air immediately surrounding an electrified body must be also electrified, and must possess the same kind of electricity with it. It is obvious that the electrical density of this air must diminish according to its distance from the surface of the excited body; hence, according to Lord Stanhope, the reason why bodies charged with the same kind of electricity *repel* each other is, that they may move to those parts of their atmosphere where the electricity is *least*. Bodies excited with different kinds of electricity, on the contrary, approach each other, because each moves towards the extremity of its electrical atmosphere. Without introducing the mathematical formulæ of his lordship, as published by him in 1779, we shall introduce the more easily-understood remarks of Coulomb, published seven years later. For the purpose of these experiments, Coulomb used his electrical balance, already described. Having electrified the two balls of the balance by means of the head of a large pin, the index of the micrometer standing at 0, the ball of the needle separated 36°. Secondly, having twisted the suspending wire 126°, the balls approached each other, and remained at 18° distance. The suspending wire being twisted 567°, the two balls approached within 8½° of each other. In the first case, the index of the micrometer being at 0, the balls separated 36°. In the second case, the distance of the balls was 18°, but as the micrometer was turned 126°, it follows that at the distance of 18° the repulsive force was 144°. Thus, when the distance is reduced to one-half the repulsive force is quadrupled. In the third case, the suspending wire was twisted 567°, and the two balls were reduced to the distance of 8½° from each other. Here the actual tortion was 576 or four times as much as in the second case, and there is only half a degree wanting to render the distance of the balls, in the third case, one half of what it was in the second. The distance being 8½° in the third case, 18° in the second, and 36° in the first. The half degree lost in the third experiment is to be accounted for by the loss or dispersion of the fluid during the experiments, which lasted four minutes. Thus it follows, that the repulsive forces exercised upon each other, by two balls charged with the same kind of electricity, are inversely as the square of the distances at which they are from each other.

We will illustrate the other laws by more popular experiments, some of which may performed by the excited glass tube, and the rest by holding towards or annexing to the prime conductor of the electrical machine the apparatus described.

Ex. 125. Suspend from the ceiling a string, and from this a feather, attached to a thread of silk, or the ball of the pendulum electroscope will do as well. Hold towards it an excited glass tube, the feather will first adhere to it, then be repelled, and if a finger be held near it, be attracted towards the finger. The attraction of the feather and tube is accounted for—they are differently electrified. The receding of the feather is also accounted for, for after touching each other they are similarly electrified ; but why the feather should seek the finger is not so apparent. It arises from a cause, which, instead of militating against the truth of Franklin's laws, does but prove the general applicability of the above. It was stated that when a body of any kind is electrified, it affects and repels the electric fluid contained in all the bodies near it, and thus the overcharged feather drives away some portion of the fluid in the finger, in consequence of which the part of the finger nearest to it becomes negative, or in a different state from itself—therefore they are mutually attracted.

126. *Diverging threads.*—Tie twenty fine linen threads together at each end, so that there may be about 8 inches distance from knot to knot; hang this by a wire loop, fastened to one of the knots, to the conductor of the machine. Upon charging the conductor, the threads will recede from each other, forming a curious balloon-shaped body.



127. *Expanding threads.* — Instead of tying the threads at both ends, let the lower end be loose, and upon turning the machine they will form a brush.

128. *The glass feather.*—Procure a glass feather, as made at the fancy glass shops, and stick it into one of the holes on the upper side of the conductor ; when the machine is put in motion the radiation of all the filaments of glass will offer a most elegant object.

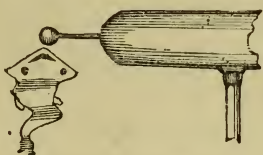
129. *The frightened head of hair.*—As a variation of the last experiment, the head of a doll is furnished with a wig of hair, which is 2 or 3 inches long ; upon electrifying this, " each particular hair will stand on end" in the most grotesque manner, and thus it is with every person who is electrified, when on a glass-legged stool. This experiment becomes most effective, because seen more conspicuously, when the hair is of a grey color.

130. *Radiating feathers.* — Let a metal ring be supported upon a glass pillar, and at six or eight equally-distant points around this ring tie a thread (not silk) a few inches long, the other end of which bears a feather. Connect the metal ring with the conductor of the machine by a wire or chain, and the feathers being electrified will repel each other until they will stand at equal distances like the spokes of a wheel.

131. *The electrified cloud.*—Take a handful of wadding or raw cotton, squeeze it together tight, yet so that the threads shall not be entangled. Place it upon a flat, smooth board, connected with the prime conductor of a machine. Upon electrifying the board, the cotton will separate itself, and expand until it becomes a large fleecy mass, and if the machine be in good action, the whole mass of cotton will fly away. Indeed it may

always be made to fly off, if the quantity be proportioned to the strength of the machine. Let it be remarked, however, that it will soon fall to the ground, not only because of the attraction it has for other bodies, but because of the gravitation it naturally has, and which is not altered in any degree by the electrization, unless an excited tube be constantly held towards it, when one power will, if strong enough, counteract the other.

132. *Electric fish.*—Cut a piece of very thin leaf brass (such as is called tinsel will do) with an obtuse angle at one end, and an acute one at the other; present the large end towards an electrified conductor, and, when the brass is within its atmosphere, let it go; it will then fix itself to the conductor by the apex of its obtuse angle, and, from its continual wavering motion, will appear to be animated.

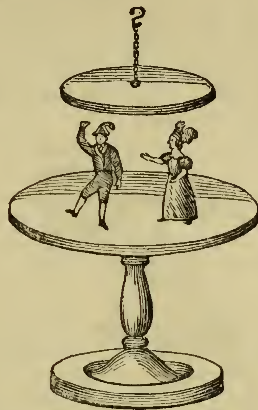


133. *Suspended leaf.*—Hold towards the ball at the end of the conductor a square thin leaf of brass or paper; upon turning the machine, it will leave the hand and be suspended with one of its points upwards between the hand and the conductor.

134. *The moving leaf.*—Move the hand round, and at a uniform distance from the ball of the conductor, when the leaf of brass is suspended near it, and it will be seen to move with the hand in any direction which the latter may take.

135. *Animated thread.*— Present a fine thread to an electrified conductor; when it is at a proper distance it will fly towards, and stick to the conductor, and convey the electric fluid from it to the hand; remove the thread to a small distance from the conductor, and it will fly backwards and forwards with great velocity, and in a very pleasing manner. Present the same thread towards one that hangs from the conductor, they will attract and join each other. Bring the finger, or a brass ball, near these threads, the ball will repel that held by the hand, and attract that which is affixed to the conductor.

136. *Dancing images.*—To the end of the conductor, suspend a plate, made either of metal or wood, covered with tin foil, and at a distance of 3 or 4 inches under this a similar plate, but one that is rather larger. Place on the lower plate any little figures cut out of paper or pith. Take care that the lower plate is supported upon some conducting substance; turn the machine, and the figures will raise themselves, and fly up and down between the two plates, forming a most ludicrous dance.

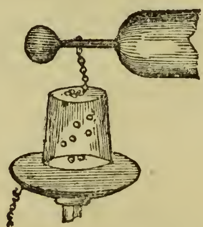


137. Support the lower plate upon a glass bottle, or other insulator, and although all the rest of the apparatus remain as before, yet the figures will not dance. The reason is this, the upper plate being charged by its connexion with the machine, the figures are attracted by it, they becoming charged are repelled by the upper, and attracted by the lower plate. When they touch this their charge is removed by that contact, and conveyed to the earth, while the figures jump up again for a fresh supply, and thus they move alternately from the one to the other plate. When the lower plate, however, is insulated, the extra portion brought to it cannot escape, and it becomes charged in the same manner as the upper one, therefore the figures have no tendency to move between them.

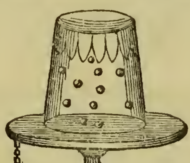
Note.—If in cutting out the figure the head is heavier than the feet, it will dance head downwards; damping the feet in the mouth will usually remedy the defect, but this, at the same time, gives them a tendency to adhere to the upper plate, while wetting the head makes them dance on the lower plate. Female figures usually dance more regularly because of the weight of the lower part of the dress. In all the figures the head should be somewhat pointed, either by the adjunct of a steeple-crowned hat, or something similar put upon it.

138. *Dancing pith balls.*—Place upon the lower stand, (mentioned in *Ex.* 136,) six or eight balls of the pith of elder, and cover

them over with a dry tumbler, Hang to the conductor a chain, which touches this tumbler; upon turning the machine, although glass intervenes between the exciting power and the balls acted upon, yet the balls will fly rapidly up and down within the glass tumbler. In this instance, the outer part of the glass is by contact electrified positively; the inner part, therefore, will be by induction, (afterwards to be explained,) electrified negatively; and the balls are flying up and down to supply the deficiency of the glass—each ball coming to deposit its load, and flying down again for another.



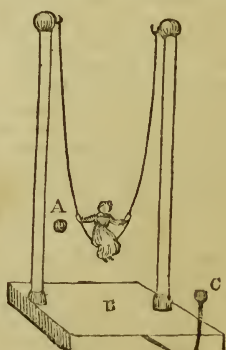
139. The dancing pith ball experiment may be reversed thus :—Fasten to the conductor a pointed wire as before. Hold a dry and warm tumbler over the point, and turn the machine. After a few turns the tumbler will be charged withinside with positive electricity. Place upon a table, or a metal plate, a few pith balls, and cover them over with the charged tumbler. They will now jump up and down, each one conveying some of the fluid away from the glass, and not towards it, as in the latter instance. They continue to dance long after the machine ceases to act, and when their motion has ceased altogether, it may be renewed by merely putting the hand upon the outside of the glass.



140. *To make pith and cork balls.*—Procure some of the thick young shoots of the common elder-tree, cut them into lengths between the joints, and push out the pith of each length by a smooth stick, as near as possible the size of the hole where the pith is, and dry it for use. When wanted for balls, cut out each ball moderately true with a penknife, and to round them more perfectly, and take off the rough edges, roll them very gently, with a circular motion, on a smooth table, and they will be fit for use Cork balls may be cut in the same manner, but to make them smooth each one must be placed upon the point of a needle, and turned round two or three times in the flame of a candle, or should the blackness thereby occasioned be an objection they may be rubbed with sand paper.

141. *Electric bells.*—The apparatus thus called is of various forms, that put into action by attraction is represented beneath: — It consists of a rod or wire, having a hook to hang it up by, and a small chain at each end, terminated by a bell. There are, also, at three other parts depending from it three silk threads, one terminated by a third bell, the other two by metal clappers. The third bell, it will be observed, has a chain appended to it which reaches the ground. When this apparatus is suspended from the conductor, the wire at top, and the bells at the sides, become electrified—these latter, therefore, attract the clappers. They thus becoming charged, recede till they touch the centre bell, and thus the motion of the clappers, from one to the other, produces the sound of ringing.

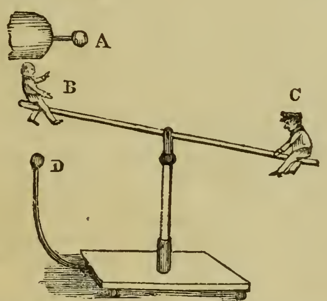
142. *Electric swing.*— Balance a small figure upon two fine silk strings, and place it within 3 or 4 inches of a ball which forms part of a conductor, while on the other side of the figure is a second ball connected with the ground. Upon putting the machine in



action, the figure will vibrate from one to the other.

The above figure represents such an instrument. A is a ball attached to the prime conductor of a machine. C is a ball connected with the ground. B is a stand above which is a figure suspended by silk, and supported by two glass pillars; though these last are not absolutely necessary, because the silk will be sufficient to prevent any charge the figure may receive from being dissipated before it arrives at C, the proper place to deposit it. The ball A may be dispensed with, if the pillars be glass, and the figure suspended on linen, the top of one of the pillars being connected with the conductor.

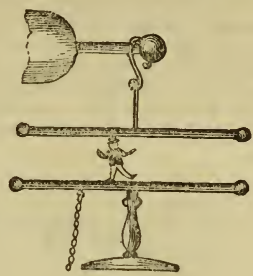
143. *The electric seesaw.*—Suspend a strip, or fine rod of glass upon a centre, and upon each end of it support a light figure of pith. Let one of the figures have no conducting substance under it, nor yet touch the conductor when swinging upwards; but let the other figure come against the ball of the conductor when it rises highest, and touch another ball connected with the ground when descending lowest; if put properly under the conductor of a machine it will vibrate up and down—the opposite figure only acting as a counterpoise to it.



This apparatus is annexed: A is the conductor. B the conducting figure. C the counterpoise; and D the part connected with the ground, to carry away the fluid brought down by B.

144. *Electrical spider.*—Cut out of a bit of cork the body of a spider; furnish it with eight white thread legs, and run through the body a long black silk thread. Hold this up in one hand, so that it shall hang 2 or 3 inches from the side of the conductor, and hold the finger about the same distance beyond it—when the assistant turns the machine the spider will fly backwards and forwards between the conductor and the finger.

145. *The electrical rope dancer.*—Suspend from the ball of the conductor two thick wires, about a foot long. The upper wire is connected with the conductor by a small chain or hook; the lower one is hung to this, at the distance of 2 or 3 inches, by a silk thread at each end; the lower wire is also connected with the ground by a chain. Place on the lower wire a paper or pith figure, and upon putting the machine in action, it will move alternately and briskly between them.



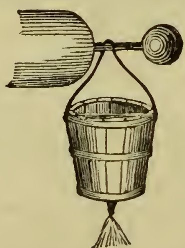
This experiment is but a modification of the dancing figures, described in *Ex.* 136. In the cut above given, the two wires appear unconnected with each other, the lower one having a stand of its own. This is a better form of the apparatus, because when connected together by silk, the figure put to dance is apt to cling to the silk, which destroys the effect intended to be produced.

146. *Spinning sealing wax.*—Fasten on to a thick wire a piece of sealing wax, about one inch long, by heating it, and thrusting the wire into it. Put the other end of the wire into a hole, either at the end or side of the conductor, so that the wax shall be at some distance off. Underneath where the wax is, either on the table or the floor, place a sheet of brown paper, merely to catch any drops which may fall when the wax is inflamed. Provide yourself also with a lighted candle, and a sheet of white paper, Direct your assistant, (for in this experiment you must have one,) to turn the machine, and stop it exactly at the time you may desire. Then standing near the wax, hold the white paper 4 or 5 inches from it, and light the sealing wax. When well lighted, blow it out, and at the same instant let the machine be turned, and exceedingly fine threads of wax will be thrown off, and collected on the white paper, as long as the wax remains melted. Stop the machine, light, blow out the wax, and turn the machine as before—more of the filaments will be thrown off, and thus any quantity may be collected, and if scraped together by the point of a pin, it will resemble the finest wool, such as cannot be procured by any other means.

147. *Electrified camphor.*—Connect a spoon or small metal cup, with the conductor

of a machine, light the camphor, and then electrify the conductor; the melted camphor will throw out the most beautiful ramifications as long as the machine is turned. This experiment is even more beautiful than that with sealing wax.

148. *The electrical pail.*—Suspend to the ball, which projects from the prime conductor, a small metal or wooden pail, having at the bottom of it a hole, so fine that water will pass only by drops. Pour a little water into it, and when electrified, the water instead of dropping only will pass out in a stream, and this will divide itself into several streams, each of which in the dark will be beautifully luminous.



149. Insulate a small condensed air fountain and electrify it; the jet will be minutely subdivided and expanded over a considerable space, but will return to its original limit when the electrization is discontinued.

150. Suspend one pail from a positive conductor, and another from a negative conductor, so that the ends of the jets may be about 3 or 4 inches from each other. The stream proceeding from one will be attracted by that which issues from the other, and form one stream which will be luminous in the dark.

151. Hang two pails about 4 inches apart on the same conductor, and the streams which issue from them will recede from each other.

152. Place a metal basin on an insulating stand, and connect it with the prime conductor; then pour a small stream of water into the basin, which in the dark will have a beautiful appearance, as the stream will be divided into a great number of lucid drops.

153. Hold a pail which is furnished with several capillary tubes, placed in various directions, near an electrified conductor, and the water will stream out of those jets near the conductor, while it will only drop at intervals from those which are opposite to it. A most remarkable exemplification of the laws of induction is seen when the vessel containing the water is made of a long form, and placed at right angles to the prime conductor of a machine, minute holes being pierced on the underside of the tube at 3 or 4 inches distant from each other. The tube should be suspended by silk. Upon turning the machine, the water from the ends will fall in streams attractive of each other, while from the middle hole it only drops. In the dark with a powerful machine, and 4 or 5 feet distance for the water to drop, this is a most splendid experiment.

154. *Conical drop.*—Place a large drop of water upon the end of a smooth metal rod; hold it to the prime conductor when excited, and the water will first assume a conical form, and then fly to the conductor.

155. Let a drop of water hang from the ball at the end of the prime conductor, and hold towards it a wine glass or spoonful of water. The one will attract the other, so that the drop will lengthen itself according to the force of the electricity.

156. *Fiery sponge.*—Suspend in like manner to the bucket a sponge dipped in water, and the luminous streams which issue from it will be more numerous and beautiful than even in the last example.

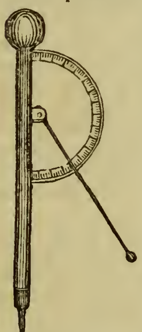
157. *Electric planet.*—Suspend from the conductor of a machine a brass ring, about a foot in diameter, and underneath it, at about ½ an inch distance, a metallic plate connected with the ground. Place upon this plate, and within the ring, a very light hollow glass ball —turn the machine, and the little ball will describe an orbit around the ring, and turn at the same time about its own axis. The poles of its rotation are nearly at right angles to the plane of its orbit. We have not tried this experiment. Mr. Adams says, "that it requires considerable attention to make it succeed, as a small difference in the apparatus, or in the force of the machine, &c., will occasion a failure."

158. *Electric swan.*—Procure a waxen swan, and which may be bought for a few pence at the pastry-cook's, who use them to decorate twelfth-cakes; cover the throat and breast very neatly with tin foil, which may be painted over afterwards to prevent its being seen; or the whole may be covered with gold leaf. Let the swan float in a basin of water, which is supported upon a glass stand, suffer a chain to fall from the prime conductor to dip into the water; turn the machine and hold a piece of bread to the swan, it will immediately turn to it, and approach as if to eat the bread. The swan may be made of cork, and if an electrical stand is not at hand, a very excellent one may be made with a wine bottle, a flat and smooth piece of wood being nailed to a peg which fits into the top of the bottle. A sheet

of paste-board or a cover of a large book made warm answers the same purpose.

159. *Electric boat.*—Make a small boat ot wood, with a cork figure apparently rowing it; upon presenting a finger, the boat will approach, and may thus be carried round the basin in which it is floating.

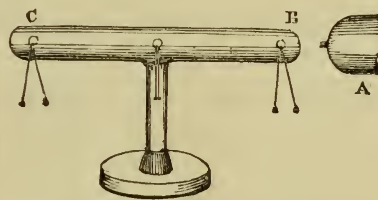
HENLEY S QUADRANT ELECTROMETER.



The repulsion which takes place between bodies which are electrified, suggested this valuable instrument, the object of which is to ascertain the degree of intensity to which any electrified body is charged, particularly the Leyden jar. It consists of a shank of wood, with a brass ferule and point at the foot, which latter fits into one of the holes of the prime conductor, end is terminated above by a wooden ball turned out of the same piece of wood, mostly mahogany. To the side of the shank and near the top, is glued or otherwise fastened a semicircle of ivory, graduated on the edge to angular measurement, so that the whole semicircle is divided into 180°, and of course the point of it most distant, or at right angles to the stem, is 90°. In the centre of the circle, of which the semicircle is the half, is supported on a pivot a very thin wooden pointer, so that it may move up and down in a vertical line. A pith ball is placed at the outer end. If this apparatus be inserted in a hole of the prime conductor, or any other object strongly electrified, the pith ball and its stem will rise by electrical repulsion, and indicate by the degree they cut, the strength of the electrization. The greatest energy or abundance of fluid will make it subtend the angle of 90°, a less degree of force 60, 50, 40, &c. degrees. This, although a useful instrument, is by no means an accurate indicator of intensity, because of the effect which gravitation has upon it. All the electrometers and electroscopes, previously described, act by the same principle.

INDUCTION.

The circumstances of electrical repulsion taking place between bodies similarly electrified is a natural consequence of the fact that the electric fluid repels itself, and attracts all other matter. Suppose there are two conductors placed as in the following cut; one

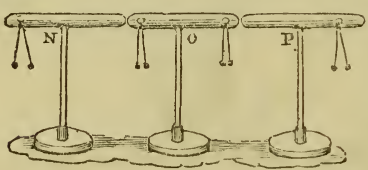


of them being a small conductor furnished with three pairs of pith balls, placed near to the prime conductor of a machine. Let that prime conductor be charged by turning the machine, and although the small conductor does not touch it, it is evident from numerous of the former experiments that it will become electrical, in the same manner as the feather did when the excited tube was held towards it (*Ex.* 9). The fluid being repellent of itself, and the end A of the prime conductor being electrified *plus*, there will be a superabundant quantity of the fluid at the end A; it will therefore repel the fluid of B C from the end B. If B C be insulated, this repulsion will drive the fluid from the end B to the end C. As A does not touch or give a spark or any appreciable quantity of its extra fluid to B C it follows, what indeed can be satisfactorily proved by other methods, that it merely disturbs the fluid of B C, driving it from the end B to that of C. B therefore will be electrified *minus*, and as the fluid driven from B is accumulated in C, it must be evident that C would be electrified *plus*, while the central point between them would be *neutral.* This may be proved by the following experiments :—

*Ex.*160. Suspend from the small conductor B C three pairs of pith balls, on fine linen threads. Turn the machine very gently, so as to cause the pith balls to diverge; they will hang as in the figure, showing a neutral point where the balls are unaffected, and two other points where the fluid is disturbed, and which are therefore charged.

161. Hold an excited glass tube to the pair suspended from B, they will be attracted to the glass, showing themselves in a contrary state to the glass; they are thereby proved to be negative. Then hold the excited tube to the pair at C, and they will be repelled, showing that the excited glass and themselves are both electrified alike, which we know is positively.

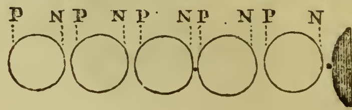
162. Try this experiment with three conductors, as in the annexed cut. When excited as before, either by the proximity of a charged conductor, or by an excited glass rod held towards them, beyond the conductor N, draw away the central conductor, and also the excited rod, the central conductor O will not be charged at all, that marked P will be positive, and that at N negative.



163. When charged as before, as soon as O is removed, place the conductor N, so as to touch P. The disturbance of both will be neutralized by each other, showing that the quantity which is plus in one, exactly counterbalances that which is deficient in the other.

164. While the last experiments are progressing, and before the conductors are taken out of contact with each other, suddenly stop the machine, or remove the excited tube, according to that with which you are operating, and the fluid will arrange itself as at first; it has become in a quiescent state, and consequently no divergence of any of the balls will take place. If there should be, it shows that the conductor has become charged with accumulated, and not induced electricity, and therefore all the pith balls will diverge with the same electricity. It has in fact positively received fluid, and not merely had that inherent in it disturbed.

165. If these three conductors instead of touching each other, had been placed a little apart, they would each have given the same results as they now do together, as it must be evident that they now act as a single body. The same would be the case had the conductors been ever so numerous, for according to the laws of electrical induction, there cannot be a body electrified positively without the nearest body to it being electrified negatively, this next body will in like manner act upon a third, the third upon a fourth, and so on. Negative and positive being always opposed to each other. Take the following illustration of a number of spots of tin foil pasted upon glass. Suppose them held near to an excited electric, all the spots would be endowed with positive and negative properties, according to the letters annexed to them.



In all cases of this kind, it must be evident that an electric must interpose between the two conductors, or they would act as one, so in the experiment of the three conductors, air which is an electric is between one and another. In the condenser described in p. 15, there is a layer of varnish between the plates, so also in the electrophorus, the resinous matter or cake interposes between the upper plate and the under plate. In the circular rubbing machine, and in the sulphur cone, although excitation is carried on, on the one side of a piece of glass, yet the effects become apparent on the other side. In truth induction takes place only because of the interposing electric. In the air we have proved that this effect diminishes according to the square of the distance. In glass the exact ratio is not stated, but in all probability it follows the same law, making due allowance for the solidity of glass as a resisting medium, and for its power of electric conductibility compared to air. It is certain that the thinner the glass is of all electrical apparatus, the more powerfully it may be charged, and the more easily excited.

The induction which so readily shows itself on short conductors, is still more conspicuously exhibited in those of a considerable length. For example, let us take the three conductors of *Ex.* 163, and while acting, let us add two more to them, the whole being joined together. The last conductor when there were three, became positive as we saw. But the fifth is now positive, and the neutral one is the third. The fluid when there were three was only driven a short distance forward, and its presence there prevented any further action, but now with five conductors it is driven twice as far as before, and therefore offers less impediment to a greater effect. It follows then that the longer the conductor, the greater is the power or effect produced. This being tried, will become evident, for when there are five united conductors, or else a conductor as long as the five, the pith balls at the ends will diverge much more, by the application of a certain quantity of electricity then when there are three conductors, or one proportionably shorter. From this it follows:—that the electric effect will be ex-

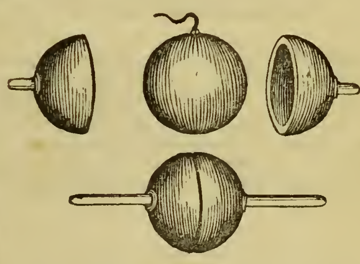
hibited much more strongly by long conductors than by short ones. If the greater electric effects are produced by very long conductors, a question relative to their greater or less diameter, or their greater or less solidity, would naturally suggest itself. Some experiments upon this subject will show us that it is not those conductors that have the greatest quantity of matter in their bulk, that conduct electricity the best, but those which have the greatest surface; hence it appears that electricity passes over the surface, and accumulates there only. Yet in violent transmissions of the fluid it appears certain that the fluid passes through the whole substance; when treating of the mechanical effects of electricity, we shall see this abundantly exemplified. At present we have only to adduce an illustration or two of the ordinary accumulation of the fluid upon the surface of bodies, rather than of its passage violently through them, and for this we have the law of Coulomb—that the quantity of fluid capable of being made apparent by excitation or transference is in proportion to the *surface of* a body along which it passes, or upon which it is accumulated. Thus a hollow cylinder is always as efficacious as one which is solid, and a large thin conductor will accumulate more fluid than a small one of more solid material. The power of a Leyden jar is always in proportion to its extent of surface, and not according to the thickness of the coating, and so on in numberless other similar instances. The following experiments have been adduced to show that in excited bodies, or those which are charged with fluid, the fluid is only to be found disturbed at the surface.

166. Support upon a glass rod a wooden ball, and bore various holes to different depths upon its surface, as represented in section below; then support a wafer covered with gold-leaf upon a very fine and dry rod of shell lac. Charge the wooden ball by holding near it an excited glass tube. While it remains charged, touch its surface with the supported gilt wafer, which immediately hold to a very delicate electrometer; this will show that the wafer has imbibed some of the electricity from the surface of the ball. Again, pass the gilt wafer quickly and neatly to the bottom of one of the holes, withdraw it, and upon holding it to the electroscope, no effect will be produced.

167. *The electric well.*—Place upon an electric stool, a metal quart pot, mug, or some other conducting body, nearly of the same form and dimension, then tie a short cork ball electroscope, that is two cork balls suspended on a linen thread, to a silken cord. Electrify the mug, and hold the electroscope within it, when it will not be at all affected.

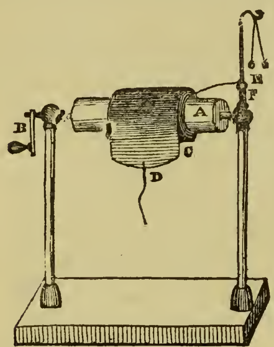
168. Instead of the electroscope in the last experiment use a metallic ball, suspended by silk ; electrify the mug and withdraw the ball, it will be found not charged by its contact with the inner surface of the mug, though it may have been struck against its sides many times.

Biot, the celebrated French electrician, constructed the apparatus shown beneath. It consists of a round metal ball, suspended by silk and covered with two caps, each furnished with a glass handle as represented, made of paper and covered with tin-foil, and such that when united, they accurately fit the surface of the inner ball. Let there be communicated to the ball any degree of electricity, then let the two caps, held by their insulating handles, be carefully applied to its surface. Upon the removal of these caps, it will be found that the whole of the electricity has been abstracted from the sphere, so that it will no longer affect the most delicate electrometer, while the two caps will be found to have acquired precisely the same quantity of electricity which had at first resided in the ball.

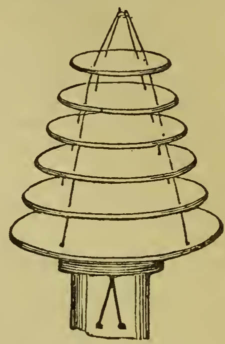


The next circumstance to be observed is the effect of an extended or contracted surface in rendering apparent a minute quantity of electricity. It is not to be supposed that the communication of a trifling amount of force will affect a large body—or, that a little fluid spread over an extended space will be so apparent as if more concentrated. In electricity, as in mechanics, the means must be proportionate to the end to be effected, and that which will influence sensibly a small conductor will be unappreciable on one which is larger. Thus electrical intensity may be less, though the quantity is the same. This is illustrated by the following experiments of Biot, Coulomb, and Cavallo.

The figure beneath represents the apparatus required. A is a roller of baked wood, wax or glass, supported upon two rods also of glass; a strip of tin-foil reaches to the central axis at the end farthest from the handle, or else there is a fine wire which reaches from the metallic ribbon or long slip of tin-foil C, to the insulated electrometer E F. G is a silk string attached to F. On electrifying the cylinder, or rather the metal coil E, the balls of the electroscope diverge; upon taking hold of the silk thread, and unrolling the metallic lamina from the cylinder, the balls gradually collapse, thus indicating a diminution of electrical intensity. Again, winding up the lamina, the balls will diverge as at first, making an allowance for a trifling dispersion of the fluid during the experiment.



169. Make a number of pasteboard plates, cover them with tin-foil, and suspend them from each other by a metallic thread, a handle of glass or a silk cord being attached to the upper plate. Let the plates rest on each other, and place the whole together upon the top of a gold leaf electroscope, electrify them so that the gold leaves diverge; then gradually draw them up by the silk thread at the top, when the diverging will diminish in proportion, and again increase when let down as at first.



170. Insulate a metallic cup, or any other concave piece of metal, and place within it a pretty long metallic chain, having a silk thread tied to one of its ends. To a wire proceeding from the cup suspend a pith ball electroscope. Then electrify the cup by giving it a spark with a knob of a charged bottle, and the balls of the electroscope will diverge. Lift up one end of the chain, when the balls will collapse, let it down again and they recede as at first.

171. Excite a long strip of flannel, or a silk riband, by rubbing it with the fingers, then holding the knuckle to it, take as many sparks as the riband will give, but when the riband or flannel has lost the power of giving any more sparks in this manner, double or roll it up. By this operation the flannel appears to be so strongly electrical, that it not only gives sparks to the hand brought near, but throws out spontaneous brushes of light, which appear very beautiful in the dark.

CHAP. VI.

INFLUENCE AND DIFFERENT EFFECT OF BALLS AND POINTS. ELECTRICAL AURA.

The preceding chapter, treating of the diffusion of the electric fluid over the surface of bodies electrified, took no account of the particular character of their terminations; it was supposed that they were all rounded off by balls, or globular terminations to the conductors. Let any of the experiments of attraction and repulsion be tried at the same time that a sharp-pointed needle is suffered to project from the conductor, or the end or side removed from the cylinder of the machine, and it will be apparent that the fluid is thereby dissi-

pated, so great is the power possessed by points in dispersing the fluid, that a single needle or pointed wire suffices to dissipate the whole fluid collected by a large machine. Hence the reason why all parts of the electrical apparatus, which is to hold accumulated electricity, must be made round and smooth. As points have, in the cases mentioned above, the power to dissipate the fluid, so if they are attached to any surrounding object within the influence of the machine, they will draw it thence. It is for this reason that a row of points is placed on the side or end of the conductor nearest to the cylinder, the fluid being thereby attracted from the glass, to which it adheres rather strongly, to the prime conductor. We learn also the necessity of removing from the machine all pointed articles, of whatever nature they may be; likewise persons who wear head-dresses, and other garments with sharp points and edges. In electrifying a gentleman, and afterwards a lady, on a glass legged stool, a very great difference is often perceptible in the strength of the spark which may be taken from each, entirely owing to the difference of their dress. We have in electrifying a lady frequently seen in the dark that the whole of the lace border of a head-dress has been perfectly luminous from the dispersion of the fluid, when of course but very small sparks could be obtained. A sharp pointed shoe is very apt to throw off the fluid, so is also a cravat pin, a metallic chain, and the point of a watch key. No dispersive effects however take place when the points of any of these articles are covered; for it is not merely sufficient that a point should be present, but that it should at all times project beyond the general surface, or no effect is produced. The influence of points is easily seen in the dark, and the very different appearances then put on by the electric light proves the law of induction before explained, in a very perceptible manner, for even the very appearance of the light at the point will immediately inform us of the nature and state of the electricity of the body to which it is appended.

Ex. 172. *Escape of the fluid to a ball.*—Hold a ball towards the prime conductor of a machine, when at a certain distance, according to the strength of the machine, a spark will pass between the conductor and the ball.

173. *Escape of the fluid to a point.*—Hold a pointed wire towards the prime conductor, and the fluid will be drawn off; but silently, and without a spark.

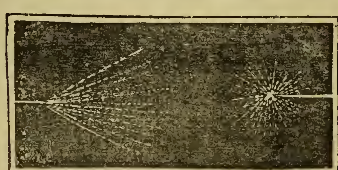
174. Hold a sharp needle at a few inches distance from a charged conductor, and try with the other hand to take a spark; it will be found that a spark will not pass to the hand until the needle is withdrawn, although the needle may have been held at double the distance at which the spark would otherwise have flown across.

175. *Brush of electric light.*—Present a pointed wire to a conductor, which is electrified negatively, a lucid cone or brush will be seen diverging from the point, and the quantity of fluid will be increased. This is best done with a machine which has an insulated cushion. In directions to work a machine in page 30, it was recommended to hang a chain from the cushion to the ground. To try the above experiment, take away the chain from the cushion and hang it to the prime conductor—then hold the point towards the cushion.

176. *Star of electric light.*—Hold a pointed wire towards the prime conductor, when in action, a *star* will be perceptible on the point, and not a brush as before.

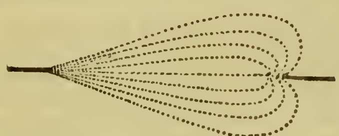
177. Attach a point to the outer side or end of the prime conductor, and a brush of light will issue from it, while a star is seen upon all of the points which are towards the cylinder.

178. Remove the conductor for some considerable distance from the cylinder, brushes of fluid will start from the cylinder, and stars seen upon the points of the conductor. Place a pointed wire on both prime conductor and cushion, and make the points approach each other; a star will appear on one and a brush on the other, the conductor parting with its fluid, and the cushion receiving it. The pre-



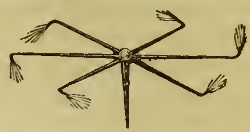
ceding will be the appearance in the dark from the two points.

179. Place a row of conductors, as in *Ex.* 162, and let each be furnished with a point at each end, all the points farthest from the prime conductor will show brushes of light, and all the others stars. The stars indicating, as will be evident, the negative state, and the brushes of light the positive condition. The reason of these appearances is thus explained by Dr. Roget. "The diverging lines on the one side, and their inflections on the other, represent exactly the paths of particles flowing out as from a pipe, and urged forwards as by a force which gives them such a projectile velocity, as to prevent their spreading out beyond a certain distance from the direct line of projection. But this very velocity will carry the particles, that happen to have deviated most, somewhat beyond the point to which they are attracted; whilst the attraction to this latter point will tend to deflect them from the line of their path, and gradually turn them back, so that they will arrive at the point of attraction by very different paths, and even some by a retrograde motion. Hence while, in the first case, they form a diverging cone of rays, in the latter they must be distributed on all sides of the point, like the rays of a star. The annexed diagram will sufficiently illustrate this explanation by representing the supposed course of the particles of electric fluid, passing through the air from the positive to the negative point."



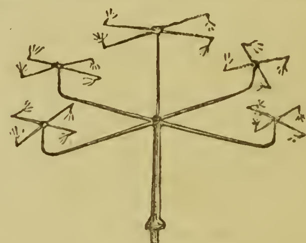
The above reason is plausible, but scarcely satisfactory, because it takes no account of the quantity of fluids emitted or absorbed, nor yet for the distance of the points from each other, or the impulse with which the fluid escapes. It also supposes two points opposed to each other, without this there is a difficulty in conceiving that the star should be equally perfect in a variety of circumstances. The following explanation appears more satisfactory. The electric fluid, by its momentum, flies off from a positive or surcharged point in a brush, like fire from a sky rocket. The negative point being a mere receiver, collects the fluid from every thing around, equally on all sides; hence it exhibits not a cone but a star of light.

180. *Electric flyer.*—Place upon the conductor a pointed wire, and balance upon this a cross or star of wires, every ray of which is bent towards the end in the same direction, as represented beneath. The fluid issuing from these various points will turn the star of wires round in the opposite direction.



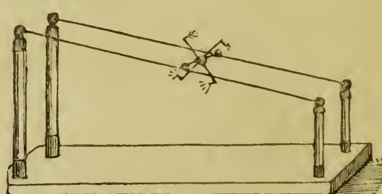
Note.—In the dark, the fluid from the various points will resemble a circle of fire, and this is rendered more brilliant if the ends of the wires are tipped with tallow or sealing wax.

181. *Compound flyer, round-about, &c.*—A number of flyers may be made to revolve at the same time, if made very light, and delicately supported. A number of similar



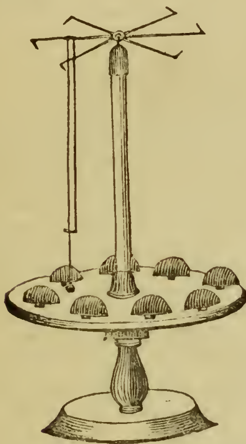
contrivances may be made as a round-about, such as is seen at fairs, provided the points which are to give it motion are properly placed—one among these is

182. *The electrical inclined plane.*—In which a flyer is furnished with a small grooved pulley at each end of an axis that bears it, it is placed on two wires which are supported by glass. When this is connected with a moderately powerful machine, the flyer immediately begins to turn round, and traverses up the wires.



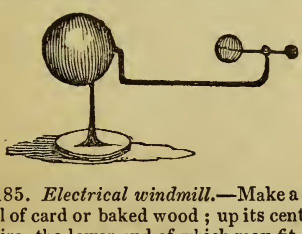
183. *Electric flyer with bells.*—This apparatus is represented annexed. It consists of a stand with differently-toned bells arranged upon it; in the centre is a glass rod, and this supports a flyer, which flyer has depending from one of its arms a wire and a silk string bearing a brass ball, (the only use of the wire

is to keep the string somewhat steady, also the opposite arm of the flyer should bear a ball as a counterpoise for the weight of the wire and string.) To use it, take away the conductor of the machine, and put the flyer in the same place as the points of the conductor usually are, when it will turn round, and the ball striking against them of course rings the bells.

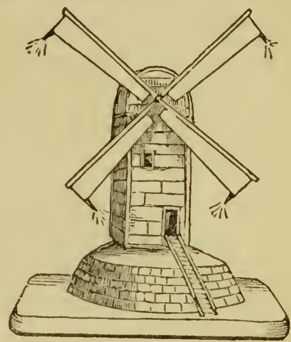


Note.—All these varieties of apparatus turn round the same way, whether electrified positively or negatively.

184. *Electric orrery.*—This apparatus is seen beneath. It represents the sun, earth and moon. The earth and moon are balanced exactly as in the last experiment; they are at their centre of gravity, upon a pointed wire, bearing at its other end the sun; this wire has a point projecting sideways near its farthest extremity. The moon also bears a side point, thus (every part being nicely balanced,) the earth and moon revolve round each other, and both together round the sun —making one of the best possible illustrations of the real motions of these heavenly bodies. The whole apparatus may be 6 inches long—the sun, &c., may be of wood.



185. *Electrical windmill.*—Make a windmill of card or baked wood; up its centre put a wire, the lower end of which may fit a hole in the conductor, the upper end must support a needle put crossways, so that its point projects through the head of the mill, ready to bear the sails. Make the sails of paper with a fine wire running along the back and end of each, a point of it projecting beyond the other edge. Let the centre of these sails be a small ball of metal, or else wood or pith gilt—fix the sails in this ball, and place the whole upon the point of the needle. Upon turning the machine the mill will revolve rapidly. This apparatus may be across the sails from one extremity to the other 4 or 5 inches—the other parts in proportion.



186. *Electric breeze or aura.*—Bring an excited glass tube near a point that is fixed to the end of a positively electrified conductor, and the luminous brush will be turned out of its direction by the action of the excited tube; if the tube be held directly opposite to the point, the brush will vanish.

187. Fix the point to the end of the negative conductor, the lucid star will turn towards the excited tube.

188. *Effect of a point to the glass feather.*—Try the *Ex.* 128 with the glass feather, and while the filaments of glass are extending in all directions by electrical repulsion, hold towards them a needle; they will be repelled from the needle, because the needle point draws away their accumulated fluid, the filaments thus restored to a natural condition adhere to the neighbouring filaments until they obtain a fresh supply.

189. Instead of a point in the last experiment, hold a metallic ball towards the excited glass feather, and instead of receding from the ball, the filaments of the feather will cling to it, because its fluid not being drawn off is attracted by the opposite state of the ball. The head of hair or divergent threads may be used instead of the glass feather.

190. Hold a point towards the electric swan, and it will recede from the hand; hold a ball and it will approach.

191. *The diving ball.*—Place a small pith or cork ball upon a tin saucer full of oil,

electrify the saucer, and hold a needle towards the ball; the ball will plunge beneath the surface immediately. To explain this, it is to be remembered that oil is an electric. As soon then as the needle is presented to the ball, it draws away its electricity, which occasions the ball either to go to the side of the vessel or to the bottom of it for a fresh supply.

192. *The travelling ball.* — Excite the brown paper of *Ex.* 4, lay it on a table and place a pith ball upon it, a quarter of an inch in diameter. The ball will run about until it becomes charged by the electricity of the paper. It will then stop, and if a needle be now presented to it, the little ball will roll away to another part of the paper. In this manner the ball may be made to roll backwards and forwards for some minutes, or until it has completely dispersed all the disturbed fluid of the paper.

193. *The pointed canoe.*—Make a boat or canoe of cork or wood, and place a figure in it, poising a large needle in the manner of a spear, let this float in water, connected with the prime conductor, and hold the hand towards it; instead of approaching the hand, the boat will recede from it.

194. Fasten a blunt pointed wire, or still better a point of wood to the prime conductor. Turn the machine, and hold your face or the back of your hand against the point, when a breeze *from* the point will be very sensibly felt. Do the same with a point placed on the cushion, and a breeze will also be felt *from* the point.

195. Instead of the face or hand, if you place a lighted candle near either of these points, the flame will be blown aside, by the breeze issuing from the point.

196. Let a feather be driven about the room by an excited glass tube, as explained in *Ex.* 14. While so driving hold to the feather a pointed wire, the feather will be repelled, although there are here two bodies near to each other, which by the law of induction we know must be electrified differently, and therefore should be attracted.

To explain this, let it be remarked that air is always blown from an electrified point, whether that point be positive or negative— a fact often brought forward as an argument in favor of there being two electrical fluids, though it seems very easy to explain the curious phenomenon by other and more simple means.

It is evident that the air in the neighbourhood of an electrified point must itself become charged with electricity, no matter whether positively or negatively. The fluid is repellent of itself, the particles of air then to which it is communicated become necessarily repellent of each other, in the same manner as the particles of sealing wax of *Ex.* 146, or those of water in the *Ex.* 148, 149, &c. Being repellent these particles escape, and the air rushing in to fill what would otherwise be a vacuity, produces a re-action sufficient to occasion the motion of the flyers and other apparatus. The reason why the fluid proceeds from the points in the form of a brush is easily accounted for—the wire of which the point is the termination is itself electrified, and therefore repellent of any particles similarly charged. The fluid in its escape must naturally then choose such a path as is the most open or free from repulsion, which will naturally be that in front of the point, and farthest away from the machine. In the case of a negative wire it is somewhat different. The negative point, as before observed, seeks the fluid from all quarters, and in drawing the fluid, as in the former case, it draws the particles of air, in which the fluid is contained, from all directions. As action and re-action are equal, it follows that as many particles as are attracted must be either absorbed or repelled — electricity is absorbed by the negative point, but not air. The particles of air then must be again thrown off, and these, which before attraction were in a natural electrical condition, have now, owing to having had their fluid abstracted, become negative. The wire and point being negative also, the particles are thrown off in a brush in the same manner as the positive particles were from the positive wire.

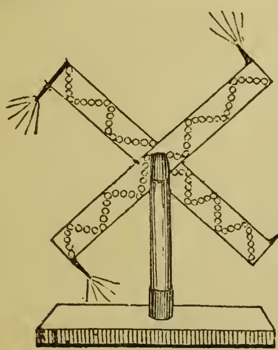
In all the above experiments the point has been free, and projecting from or towards the electrified body, and also has had an uninterrupted communication with the ground, or with the body electrified. Were either of these circumstances altered, the point would not act as we have seen it, but rather in the same manner as a ball would; that is, the fluid would either not be drawn off at all, or it would pass away with sparks, or sudden interrupted flashes.

197. Stick several needles into a piece of cork or other matter, so that their points may not be covered, place this mass of points at the bottom of a tin mug, with smooth edges, electrify it well, and if the needle points are below the edge of the mug, none of them will be luminous, showing that none are giving off the fluid.

198. Thrust a sharp pointed wire through the centre of the rind of half an orange, so that the rind forms a cup around it. Let not the point project beyond the edge of the rind, and holding it towards a charged conductor, no effect will take place, except the general attraction of the fluid for the whole of the apparatus. Now project the point forwards by little and little, then as soon as it emerges from the rind, the peculiar silent action of drawing off the fluid commences, and a star of light becomes visible.

199. Drill in a brass ball, which is 3 inches in diameter, a conical hole, which is about as large as a farthing on the outside, and tapering towards the centre; drill a small hole through the opposite radius of the ball to admit a pointed wire. Let the wire project 2 inches beyond the ball on the side of the wide opening of the hole, and hold it to the prime conductor when charged. Taking the ball which ought to be of metal, or wood covered with tin-foil, in one hand, and the blunt end of the pointed wire in the other; the projecting point will draw away the fluid silently. Still holding the ball steady, gradually withdraw the wire, when it gets near to the surface of the ball, it will take a small spark, and when drawn further in as strong a spark as if the ball alone were there.

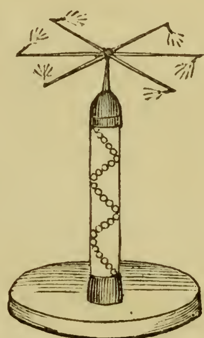
200. *Electrical cross.*—Form a cross of two thin leaves of talc, and paste upon them spots of tin-foil, just or nearly touching each other, and with a wire point at each end support this very nicely, as represented, on two wires. Place it near the prime conductor, and turn the machine, when the fluid passing from the centre to each of the points will produce beautiful streams of light, constantly in motion in consequence of the rotation of the cross.



Note.—This cross may be made horizontal instead of vertical. This experiment is given in the *Annals of Electricity*, but we doubt its success, as the points take sparks, and do not throw off or attract the fluid in brushes.

201. Hold towards the ball of a charged conductor a spiral tube, furnished with a ball at the end, and contrary to the usual character of a point it will take a spark. This is owing to the interrupted nature of the conductor which connects the point with the hand or with the ground.

202. Support a pointed spiral tabe, as represented beneath, and have a flyer affixed to the upper end; place it near to a charged prime conductor, when the fluid passing into the points turns the flyer on its axis.—*Ann. Elec.*



203. *To pierce a vessel of oil.*—Partly fill a thin phial with oil, cork it, and thrust a bent wire through the cork, so that the lower end of the wire shall be about ½ an inch below the surface of the oil. Let there be a ball at the upper end of the wire. Take a spark from the prime conductor by the ball, holding the phial so that the thumb rests on the outside of the phial opposite to the point. Although the wire is pointed at the lower end, yet the spark will be so strong as to perforate the glass. The oil will be curiously agitated. This experiment appears most beautiful when made in the dark. After the first hole is made, turn the end of the wire round towards another portion of the glass tube, and a second hole may be made in the same manner. The spark appears larger when passing through oil than when passing through the air.

Other effects of points will manifest themselves through every part of the subject.

CHAP. VII.

ELECTRIC LIGHT AND SPARK. LUMINOUS TRANSFERENCE.

The electric fluid shows itself in the several forms of a diffused light, of a brush, a star, and a spark, which spark varies in intensity, so as to be at some times scarcely perceptible, and at others, (when occasioned by the rapid progress of an immense quantity of the fluid;) like a flash of intense brilliancy; sometimes straight and undivided, at others long and zigzag; also of various colors and degrees of vividness, according to the nature of the conductor whence it is taken, or the density and character of the air, or other electric through which it passes. In the more gradual dispersion and weaker manifestations of the fluid, no noise is perceptible, a mere phosphoric appearance presenting itself as in *Ex.* 17 and 20; and as may be tried also by any of the experiments of the last chapter; for example, if the flyer, *Ex.* 180, be made to revolve in the dark a circle of brilliancy will be perceptible. Another effect is perceptible in *Ex.* 202. If a large quantity of fluid be escaping from a point, a whizzing noise becomes apparent. With a little more forcible emission of the fluid the whizzing becomes changed to a crackling, and the phosphoric light to a series of minute sparks. The noise and brilliancy increases in proportion to the impulse and quantity of the fluid, until a flash of lightning and a clap of thunder exhibits the most violent effects of its sudden passage from one overcharged body to another in its neighbourhood which by induction is dissimilarly electrified. These effects however are only the same in the same circumstances. Thus a negative spark is usually red, short, and straight. A positive spark is of a bluish white, long and zigzag. This only supposes that it is taken in the usual condition of the air, and from one metallic ball to another; for in rarefied air the noise ceases, and that which would in the atmosphere have been a concentrated and rapid spark, becomes a series of large, long brushes of diffused fluid. The same taken from different woods or other matters, or through various gases, becomes changed in color, no less than brilliancy. The brilliancy is also very greatly influenced by the distance at which the spark is taken. If the machine be put into action, and nothing be presented towards the terminal ball of the prime conductor, the fluid will escape in fitful flashes into the atmosphere around. If any round conductor be held in the hand, or if the closed hand itself be held at some distance from where these flashes issue, they will be seen to have a tendency towards it, and as the hand is made to approach to the prime conductor, so they will take a determinate form, color, and noise; first, when at the greatest striking distance, they will appear as faint, blue, and very zigzag sparks, like distant weak lightning; bringing the hand a little nearer, the sparks are more vivid, and consequently, whiter—they are thicker, well defined throughout their whole length, zigzag as before, and attended with a louder and quicker snap. At a less distance still, the brilliancy and snap is further increased; while the zigzag character is by degrees lost, unti at length the spark is so rapid as to be almost continuous, short, thick, and straight, as we see in that dangerous, though rarely witnessed kind of lightning, in which the heavens seem to burst, and pour down a short perpendicular stream of intense volume to the earth, killing and destroying every thing within many yards of its passage.

Such is the electric spark, and it may be advisable to remark, before proceeding further, how it is that the power of an electrical machine should be estimated. It is

common to hear a person observe, relative to some machine, that it will give a spark so many inches long, without stating how such a spark is to be measured. If he take all the forks of the zigzag into account, undoubtedly it will much increase the measured distance ; but this is not fair—still less is it to measure the spark upon the excited cylinder, for here the repulsion of the fluid from the overcharged conductor is assisted by the charged surface of the glass itself, and the attraction of the negatively-charged cushion. The true length of spark which a machine will give is to be measured by the distance between the terminating ball of the prime conductor, and a metallic ball held in the hand, when approaching them gradually to each other, and (the machine being in good action) a spark will pass between them. By this means of measurement, the real power of a machine may be known. The explanation of induction will have shown that the longest spark is always to be obtained from the end of the conductor, and also that the conductor should be of a considerable size. The sound is occasioned by the momentary agitation into which the air is chrown by the passage of the fluid. Also the object which takes the spark should be round, and presented quickly towards the conductor.

Ex. 204. *To obtain a crimson spark.*—Take a spark through a ball of box-wood, and it will appear of a beautiful crimson. This is better done with a shock from a Leyden jar, as it is only a very strong spark taken exactly through the centre of the ball which will succeed, and even then it is very apt to pass over the surface.

205. *A red spark.*—Wrap a piece of gilt leather over a metal ball, and take a spark with the surface of the leather, and the spark will be red.

206. *Green spark.*—Use a piece of silver leather instead of gold, and the spark will appear of a green color.

207. *Red spark.*—Take a spark from the conductor with a wet cabbage or other large leaf covering over the hand, and it will be of a red color.

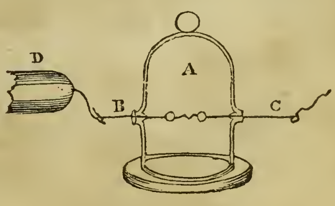
208. Place upon the conductor of a machine a little cup full of water, or else place upon the table a tumbler full of water, with a chain which reaches from the conductor so as to electrify the water. If now a spark be taken from the surface of the water by a metallic ball, or still better by the finger, the spark will be red.

209. Place a piece of ice on the conductor, and take a spark with another piece of ice, and the spark will be very red. Ice is, when below 13° of temperature Fahr., an electric, and therefore will not take a spark, but in a room it would necessarily be covered with a film of water. This would act sufficiently as a conductor, so that a small spark may be taken readily by this substance.

210. *Yellow spark.*—Lay upon a dry sheet of white paper, a train of powdered charcoal, and take as long a spark from it as it will give, one end of the train being connected by a chain or wire to the prime conductor, and the other end having the knuckle or ball held in the hand presented to it; gradually approach the ball to the charcoal, so that the fluid may run along it, and the spark will be of a yellow color.

211. *Prismatic colors in electric light.*—Take a triangular glass prism, and hold it near the eye, while any luminous experiment is being performed, and the seven prismatic colors, or colors of the rainbow, will become evident, showing that the electric light is of the same nature as that of the sun.

212. *Brilliant blue spark through nitrogen.*—Pass a spark through a vessel filled with nitrogen, and it becomes intensely brilliant, and of a splendid blue color, equal to that of burning brimstone. The apparatus, which is convenient for trying experiments of this kind, is as follows :—A is a glass receiver, holding about a pint, it has a wire and ball inserted in two opposite sides B and C. B is capable of sliding backwards or forwards, so that it may be made to approach or recede from the other. The receiver is placed in the pneumatic trough, and is filled with the required gas, in the ordinary way practised by chemists. For some gases a mercury or oil trough must be employed. During the experiment one of the balls must be connected by a wire with the prime conductor as at D, and the wire of the other held in the hand.



213. *Spark through oxygen, whitish.*—Pass a spark through oxygen gas, and it will be whiter than in the air, and also *less* brilliant. The effect in these two gases is singular, the brilliancy of the spark being increased in the nitrogen, which is not a supporter of combustion, and decreased in oxygen, the best supporter.

214. *Spark through hydrogen, reddish.*—Pass a spark through a very strong small tube, filled with pure hydrogen, and it will be of a red color. In this experiment you must be very careful that the vessel be entirely filled with hydrogen, for if a small quantity of atmospheric air or oxygen be present, explosion will ensue.

215. *Spark through carbonic acid gas, greenish.*—Pass a spark through carbonic acid gas. The spark will be very similar to that in air, except that it will have a little green in it. It is more irregular than in air.

216. *Spark through chlorine, whitish.*—Pass a spark through chlorine, and the sparks are very white, and bright throughout, never presenting those dark intervals that appear in sparks drawn through air, azote, or other gases.

217. *Variously colored through coal gas.*—Use coal gas instead of the above; with this gas the spark is sometimes red, at others green, and both colors often appear in the same spark. The result is here worthy of observation. Coal gas being a composition of carbon and hydrogen, and the spark being red with hydrogen only, and greenish with carbonic acid gas, the nearest approach we have to pure carbon in a gaseous state. Yet not merely in the chemically united coal gas, but also in the mechanical mixture of carbonic acid and hydrogen, both colors are perceptible. It is to be supposed that the gases become polarized and disunited by the passage of the fluid through them.

218. *No spark through acid vapors.*—Use a volatile acid, such as fluoric acid, nitric acid, hydrochloric acid, or sulphurous acid. Pass it up to the top of the mercury, and very little light, if any, will be apparent, acids being so good conductors, that the fluid passes readily and invisibly though them and their vapors. A mercurial trough, instead of the usual pneumatic trough must be used in the experiment, and in others where a gas or vapor condensible in water is necessarily present.

In proportion as the rarity of any medium is increased, a less intensity of electricity is required to render it luminous, and a spark becomes extended in proportion to the rarefaction of the air through which it is made to pass. Thus if the fluid be only sufficiently strong to cross an inch space in a vessel filled with air, it will pass through 2 inches if the air be exhausted one-half; and 4 inches if the rarefaction be continued to one-fourth the original quantity, and so on to greater amounts. It assumes a more diffuse and brush-like form, and a different and fainter color; passing through vapors, more or less rarefied, will also produce other effects.

219. *Indigo light through the Torricellian vacuum.*—Seal a short wire within one extremity of a glass tube of 30 inches long, so that the wire may project a little within its cavity, and screw a ball on the external end of the wire; fill the tube with quicksilver, and invert it in a basin of the same; a vacuum will be formed in the upper part of the tube, which will occupy most space when the tube is vertical, and gradually diminish as it is inclined. A spark which in the open air would pass through only $\frac{1}{4}$ of an inch, will pervade 6 inches of this vacuum with facility; and if the quicksilver be connected with the ground, a current of faint indigo-colored light will pass through the upper part of the tube, whenever its ball is brought near an electrified conductor.

220. *Blue and purple light in watery vapor.*—Previous to the inversion of the tube, let a drop of water be placed on the mercury at the open end, and secured by the finger; whilst the tube is inverted, it will rise to the top, and when the finger is removed, and the quicksilver descends, the water will expand and extend the vacuum, and through this expanded vapor a current of electricity will become luminous, and of various blue and purple colors, according to its intensity.

221. *Beautiful green light in etherial vapor.*—Instead of water, use a few drops of ether, invert the tube, and pass a stream down it. If the spark be strong, the flashes will appear of a beautiful green color.

222. *Green color in hot mercurial vapor.*—Fill the glass with very hot mercury, or, still better, suffer it to boil in the tube itself, and then invert it. The color of the light within, and which passes through the vapor of mercury, will, if the tube be very hot, be of a bright green color, and very brilliant. As the temperature diminishes, it loses its vividness, and when cooled to 20° below zero Fahr. it is invisible. It is then in fact a perfect vacuum, as there is no air present, and the vapor of the mercury which first filled the tube is condensed.

223. *Color altered by degree of exhaustion.*—Admitting to the above a very small quantity of air, and gradually and slowly increasing it, the flashes are at first green, then sea green, then blue, and then purple.

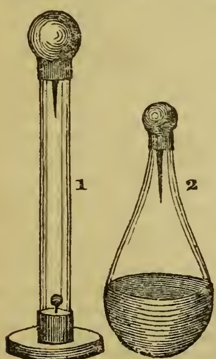
224. *Faint yellow in the vapor of tin.*—Make a vacuum by means of fused tin; the electric light at temperatures below zero will be yellow, and very faint indeed, requiring almost absolute darkness to be perceived.

225. *Reddish purple in vapor of oil.*—Make a vacuum in a similar tube with boiling oil, the light will be of a reddish purple, and much more brilliant than that through the vapor of mercury.

226. *Pure white light.*—Make a vacuum above chloride of antimony, by boiling it in the tube. This salt boils at 388°. The light is of a pure white and very brilliant.

227. Take an air pump receiver of 12 or 14 inches high, adapt a wire, pointed at its lower extremity, to the top of the receiver, letting the point project an inch or two in the inside. Place the receiver on the plate of the air pump, and electrify the wire at its top positively. Whilst the air remains in the receiver, a brush of light of very limited size only will be seen, but in proportion as the air is withdrawn by the action of the pump, this brush will enlarge, varying its appearance, and becoming more diffused as the air becomes more rarefied, until at length the whole of the receiver is pervaded by a beautiful blush of light, varying its color with the intensity of the transmitted electricity, and producing an effect which is in the highest degree pleasing.

AURORA FLASK AND TUBE.



An instrument is sold by the philosophical instrument makers to show the passage of the fluid through rarefied air, without the employment of an air pump. It is represented at A beneath. Fig. B is also a similar instrument varied only in form; the description of the one will therefore serve for the other. A, which is called the *exhausted flask* or *aurora flask*, may be made of a common oil flask, though sold usually of three or four times the size. A portion of the thicker end is covered with tin foil on the outside sufficient in quantity, that when held by the hand, the glass itself may not be touched. The neck is fitted with a brass cap and ball, with a pointed wire projecting inside. This ball should take off and show underneath it a screw, with a valve opening outwards, that the flask may be partly exhausted of air. No tin foil is necessary inside. B is a long wide tube of glass, fixed to a foot, and furnished with a cap and ball, and pointed wire at top, with the valve at the foot. By means of the valve in either of these instruments it is exhausted partly of air, by means of the air pump, then the ball being screwed on A and the foot on B, both will be fit for use. B is usually called the *aurora tube*, the appearance presented when electrified being exactly that offered by the aurora borealis in high latitudes.

Ex. 228. *To imitate the aurora borealis.*—Make the flask very hot before the fire, hold it by the tin foil, and hold its ball to a charged prime conductor. Very long and brilliant flashes will pass along the partly-exhausted flask. The same thing occurs when the long tube is held to the conductor, or placed on the table near the conductor. The flashes will continue long after the removal of the tube from the machine.

229. A result of the same nature, but far more beautiful, is seen when the aurora tube is 3 feet long and 4 inches wide, and which has a wire through the upper part of it, that may be pushed up and down; two plates are placed inside, one a fixture near the bottom, the other moveable up and down by the wire, so that the plates may be made to approach and recede from each other. The fluid will in this apparatus pass in a continued and beautiful stream.

230. While you are trying either of these latter experiments, place a hand against the side of the receiver or tube, as the case may be, and the fluid will be attracted by the hand towards the side of the vessel.

231. Take the aurora tube B, warm it, thoroughly exhaust it of air, and while attached to the air pump, hold one hand at the top, while with the other hand holding an amalgamated leather, excite the outside of the tube, faint flashes of light will appear in the inside of the tube, showing that one side of the glass is excited when the friction is applied to the other. The success of this experiment depends entirely upon the degree of exhaustion.

232. Exhaust the aurora tube B of air, and fill it with nitrogen, the flashes of light now seen will be of great beauty. Draw away by a condensing syringe half the con-

tents of nitrogen, and the flashes will be of a fine white color, and present one of the most brilliant appearances that the whole science presents.

233. *Light in rarefied gases.*—Exhaust the tube, and introduce oxygen, the flashes will be now very close and compressed, and of a whitish color, but not brilliant. When a small quantity only is introduced, the form and appearance are better, but still the appearance is not so good as with common air.

234. Invert the tube and introduce a very small quantity of hydrogen; the brushes are very fine in form and distinctness, but of a palish red color, and with a soft velvety appearance. When the gas is very much rarefied, the flashes are of a pale green.

235. Instead of the above, use the coal gas, and the brushes are short, strong, of a greenish color, and difficult to produce, unless very much rarefied.

236. Use now carbonic acid gas. This produces a very poor brush, of a reddish purple color.

The transference of the electric fluid in the state of spark presents to us numerous experiments equally beautiful, though very different in character from those which we have shown when the light passes through different media. The length and brilliancy of the spark being accordant with the strength of the machine, or the degree of intensity with which the conductor is charged, it follows, that the rapidity with which sparks would be given off is also dependent upon the same cause; thus by the aid of a powerful machine we may produce so rapid a succession as to illuminate a whole apartment, and if we diminish their size we may in the same proportion increase the number of sparks in a given time; hence the origin of what are called *luminous devices*, *luminous words*, &c., and which are among the most beautiful of electrical experiments. They all are contrived upon the fact, that if you interpose an insulated conductor between a charged body and another, which is receiving a spark from it, you change that spark into two sparks; if you interpose two such objects, you occasion three sparks, and so on; that is, the fluid having a tendency to fly off from a charged conductor to the ground, or to a negative body near it, takes always the nearest course, and is not diverted from its path by intervening conductors provided they are insulated; if they are not insulated, of course they form the nearest passage for the fluid, and it will go no farther than to the nearest of them, when it will at once pass away. The explanation of this effect will at once be attributed to induction, especially as adverted to under *Ex.* 165. In making electrical devices, the following rules are always to be borne in mind. 1st: That the sum of all the spaces on the glass, between one piece of tin-foil and another, must be much less than the length of the spark which the machine will give; in fact, altogether this aggregate space should be less than an inch. 2nd. The fluid always traverses from the prime conductor to the earth, and will, other circumstances being equal, always take the shortest course. 3rd. If the spaces in any two lines of dots be greater than the distance between that line and the next, the spark will fly across the lines, instead of going along both of them. 4th. The least possible space between one dot and another is sufficient, even if it be as fine as a hair. 5th. The lines must never cross each other, unless on different sides of the glass. 6th. When used they must be quite dry and warm.

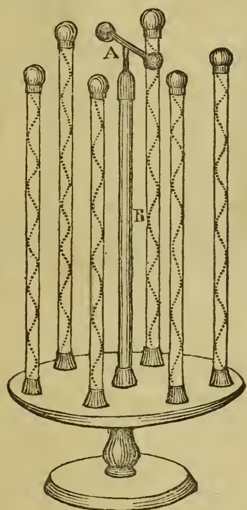
237. *Shot chain.*—Cut a number of shots half in two, and string them on a thread of black silk, at the distance from each other and of the size shown beneath. Take 1, 2 or 3 inches in length of this chain, according to the strength of the machine, and holding one end of this in the hand, take a spark with the other end. The spark instead of being single will appear distinct at each interstice between the shots, so that the whole has a most beautiful and interrupted luminous appearance.

238. *Luminous spangles.*—Sew a number of metallic spangles upon a black silk ribbon very nearly to touch each other. Suffer a spark to run along the spangles, and a beautiful line of light will be visible. The ribbon may be a foot or more in length.

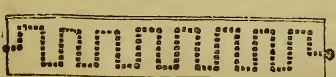
239. *Spiral tube.*—This consists of two glass tubes, placed one within the other. On the outside of the inner tube are fastened, with *common paste*, spangles of tin-foil, (punched out of the sheet of tin-foil with a small hollow punch;) the two ends of the tubes are wrapped round with tin-foil, and cemented each into a brass cap, taking care that the tin-foil at the ends, and the spangles and the brass caps are all in contact with each other. To use the spiral tube, hold one end in the hand and the other apply to the conductor, when a spark will pass along the whole length.

240. *Set of spirals.*—This is an experiment of extreme beauty. There are six spiral

tubes set round a stand in a circle, the under part is covered with tin-foil, connected with each spiral, and with the lower stand, to convey away readily the fluid. B shows a glass pillar in the centre, and A a brass wire terminated by balls, which turns freely upon the top of B, so that as it revolves, it shall come very near to each of the spiral tubes in succession; the top of A is placed so near to a ball which hangs from the prime conductor of a machine, that sparks may pass in rapid succession to the centre of A. If while the apparatus is thus placed, A be turned round by the hand, it will communicate a spark to each of the spirals in its rotation, and they will rapidly be illuminated.

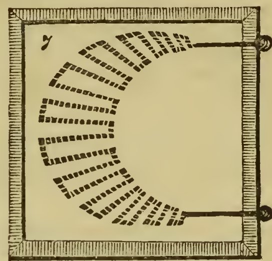


241. *Devices on glass.*—Procure a piece of common window glass, 3 inches wide, and 12 or more long. Make a design on paper of the device you desire to have; lay this beneath the glass; then cover the upper surface with common paste, and with the point of a knife, or top of a pencil, place a series of tin-foil spangles, according to the figure you have drawn. Press the pieces down so as to lie flat, then let it dry. When dry, wash off the superfluous paste, and put a brass ball or bullet at one end, when the device will be fit for use; the bullet or ball may be prepared by holding it in a vice, and cutting it about half through so as to admit the edge of the glass. Upon holding this at one end, and taking a spark by the other, the device will be illuminated. These devices



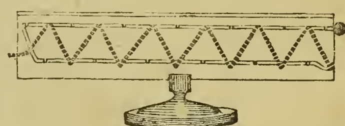
are better made without any frame; if they have a frame, it must be of baked wood.

242. *Luminous crescent.*—This is best made by straight strips of tin-foil pasted on, and connected at the edges as shown beneath, and then the places for the sparks cut with a knife.

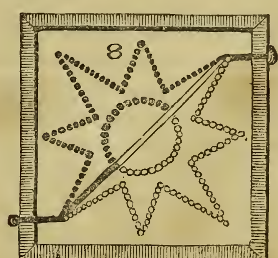


Note.—It is usually supposed to be necessary to make a cross cut at the luminous places, and to peck out the two small corners thus liberated. This, however, is quite unnecessary, merely drawing the knife across is quite sufficient. It may be advisable to state, that after the strips are pasted on, they should be suffered to dry, and the general surface carefully washed with warm water before cutting them across.

243. The following device is made on both sides the glass; the spangles being on one side, the straight lines on the other.

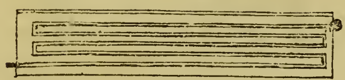


244. It is sometimes extremely difficult to arrange the strips when both sides of the glass are to have a certain portion, as in the following star, where it is evident that the fluid would not run round if the spangles were placed all on one side, as it would at once pass away to its destination, the hand. It must however be made to travel over the



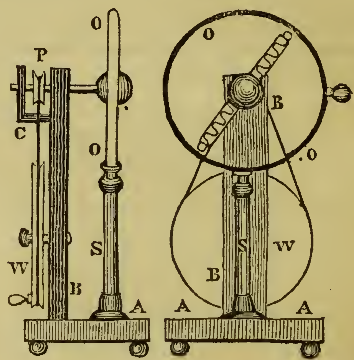
whole distance. By the different shading of the cut, it will be seen what must be pasted on the one side and what on the other.

245. *Luminous word.*—In the same manner a word, such as *electric fire, light, &c.*, may easily be made. It is best done by pasting the tin-foil in a whole piece over the glass, and laying a flat ruler upon it, cutting the various lines, and then tearing off the tin-foil which covers the intervening places. By this means the lines may be preserved straighter than by the other method.



Devices of this kind may be further ornamented by colored varnishes spread over them, which will cause the spark to be varied in color, when seen on that side upon which the varnish was placed.

246. *Revolving spiral.*—The following apparatus is the contrivance of Mr. Sturgeon. The figures beneath show the front and side appearance of the apparatus, the same letters applying to each. A A is the foot board. B B an upright wooden support. C a staple which forms with the top of B a support for the axle and small pulley P. A cord passes from this to the multiplying wheel W. S is a glass stem upon the top of which is the wire ring O O. The axis is terminated in form by a brass ball, on the two opposite sides of which are two short spiral tubes; these are put in motion by the wheel, cord and pulley. If while the spiral is made to revolve, sparks be taken from the machine by the ball shown on one side of the ring O, they will pass down the spiral tubes, and produce a most beautiful effect.



CHAP. VIII.

THE LEYDEN JAR AND ELECTRIC SHOCK.

The year 1745 was famous for the most surprising discovery that had yet taken place in the science of electricity. This was the wonderful accumulation of its power by glass, or the means of concentrating its effects by the Leyden jar, as it is called, and which took its name from Mr. Cuneus, a native of Leyden, who was led to its discovery as follows:—Observing that electrified bodies, exposed to the common atmosphere, which is always replete with conducting particles of various kinds, soon lost their electricity, and were capable of retaining but a small quantity of it, he imagined that were the electrified bodies terminated on all sides by perfectly dry electrics, and removed from the conducting influence of the surrounding air, that they would be capable of attaining a stronger power, and of retaining it a longer period. The easiest method that suggested itself was to inclose a conducting body in a warm glass phial. He tried with common water in a phial, corking the phial, and thrusting a wire through the cork, which touched the water. After taking a few sparks from the machine to the wire, and holding the phial by the outside, he removed it from the machine, and endeavouring afterwards to take out the wire with the other hand he felt a *shock* immediately in his arms and breast; this being quite unexpected was a matter of great astonishment, and it may be added, terror also.

It was this astonishing experiment that gave *eclat* to electricity. From this time it became the subject of general conversation, every body was eager to see, and notwithstanding the terrible account that was reported of it, to feel the shock, and in the same year in which it was discovered, numbers of persons in almost every country in Europe, got a livelihood by going about and showing it. The Leyden jar is nearly as simple now as it was then, and easy as electrical instruments are to make and manage generally, this is one of the most so. It has just been stated, that water was placed within the phial, and the hand on the outside. These acted not from any peculiar virtue in the hand and in the water, but merely because they were both conductors, and of course any other conductors, if equally good, would be equally efficacious. We have shown that metals are the best conductors of all; it follows then that partly lining and covering the phial with a metallic substance, as brass dust or tin-foil, will be still more efficacious, as well as more convenient, as it leaves the hands at liberty and prevents the annoyance and dampness of water. A Leyden jar then described as lined and covered with tin-foil, differs in principle in no degree from Mr. Cuneus's bottle of water, and the explanation of the one therefore becomes that of the other.

THE LEYDEN JAR

Consists of a glass phial or jar of any size, it is usually made with a large mouth, for the sake of convenience. The lower part is lined with tin-foil, to about 2 inches from the top; the outside is also covered with tin-foil up to the same line, as is seen in the cut. There is a wire, with a ball at top, connected with the inner coating. The jar is now complete, and being dried and slightly warmed, is fit for use; for the greater convenience of holding the ball and wire tightly, the jar is usually made with a wooden lid at top, and a chain reaching from the wire, which is fastened to the lid, down to the bottom of the phial, where it rests upon the inner coating. When there is a lid, it should be made of baked wood, and turned with smooth edges.

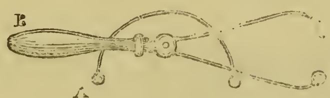
Ex. 247. *To charge and discharge a jar.*—Place the brass ball of a coated jar in contact with the prime conductor, while the outside communicates with the table, turn the cylinder, and the bottle will in a little time be charged. To discharge the jar, or restore it to its natural state, bring one end of a conducting substance in contact with the outside coating, and let the other be brought near the knob of the jar which communicates with the inside coating; a strong explosion will take place, the electric light will be visible, and the report very loud. If it is coated very low this part of the surface may be charged very high, but a considerable part of the glass is not charged at all. When a jar is charged very high, it will often explode or discharge itself over the glass from one coated surface to the other; or, if the glass is thin, it will make a hole through it, and swell the coating on both sides, the glass in the hole will be pulverized, and very often a variety of fissures will proceed from it in various directions.

248. *To receive the shock.*—Charge the Leyden jar; then touch the outside coating with one hand, and the knob with the other The jar will be discharged, and a sudden peculiar sensation will be perceived in the wrists, arms, or chest, according to the size of the phial. This is called the electric shock.

249. *To communicate the shock.*—Let the several persons who are to receive the shock arrange themselves in a line or circle as most convenient. Let them carefully join each other's hands without gloves, let tne person at one end of the line take hold of a chain which is connected with the outside of the bottle, and let the person at the other end of the line touch the knob of the bottle when charged. The shock will pass along the whole line of persons. In receiving a shock in this manner persons are generally unwilling to be at the either end of the line, thinking that it is stronger there than in the middle of the line, but this is a great error, as they all receive it equally, and would do so if there were a regiment of soldiers receiving a shock at the same time.

250. *To pass the shock without feeling it.*—As shocks are not agreeable, the electrician generally discharges the phial by means

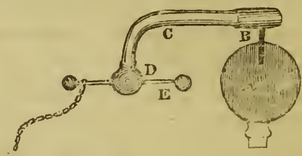
of what is called a discharging rod. This is either a semicircular piece of wire with a ball at each end, or else two wires with balls at the outer ends, and jointed at the lower ends where they are received into a socket, into which a glass handle is fastened. Hold the common discharging rod firmly, and discharge a phial by it, he will not receive a shock. If the phial be a very large one, or if he hold it lightly, he will feel perhaps a slight tingling of the fingers, when the shock passes, but this is all. If he be furnished with the glass handled discharging rod, or jointed discharging rod, as it is called, he may by setting its knobs at a proper distance, discharge even the largest battery without danger. It is usual for the sake of convenience to fasten a chain to one of the arms of the discharging rod, which communicates with the outside of the phial.



251. *To ascertain the intensity of a charge.*—Fasten the quadrant electroscope, (described in page 39) to the conductor, or if more convenient to the knob connected with the inside of the phial. As this latter becomes charged, the stem and ball of the electroscope will rise up until it attains 85 or 90°, when the bottle will be fully charged, consequently no greater effect will ensue upon turning the machine longer.

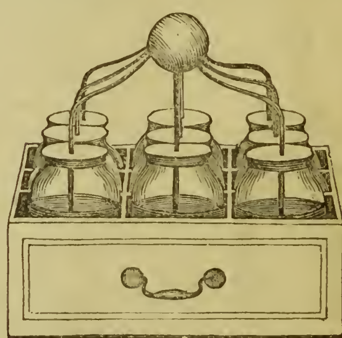
DISCHARGING OR MEDICAL ELECTROMETER.

A bottle will endeavour to throw off its electricity from the inside to the outside, the more as it becomes charged with greater intensity, as observed in *Ex.* 244, and if the two coatings be placed so close to each other, that the attraction between the two coatings overcome the resistance of the glass, a discharge necessarily takes place. On this fact the discharging electrometer is constructed. A is supposed to be a cross section of the prime conductor of an electrical machine. B is a brass cap, forming the end of the electrometer. It is made with a wire beneath to fit the hole of the conductor. C is a bent glass tube. D a brass ball at the end of it. E is a wire with a brass ball at each end, which wire is moveable backwards and forwards. When a shock is to be taken, the ball E is placed at a certain distance from the surface of A. A is connected with the inside of the Leyden jar, which communicates the shock, and the chain is connected with the outside of the jar. When the jar is charged to such a degree of intensity, as to acquire force enough to strike across from A to E, the discharge will spontaneously take place. The ball at E must be set at a greater or less distance from A, according to the strength of shock required. If a shock is to be given to a company, when this electrometer is to be used, they must form part of the circuit between the outside of the bottle and the electrometer.



ELECTRICAL BATTERY.

A series of jars is called an electrical battery. This powerful instrument is so arranged that all the outside coatings are connected together by standing in a box lined with tinfoil; and all the inside coatings are also connected by their wires meeting in a ball at the top. It is charged and discharged in the same way as a single jar, and has of course precisely the same effect, but proportionably more powerful.

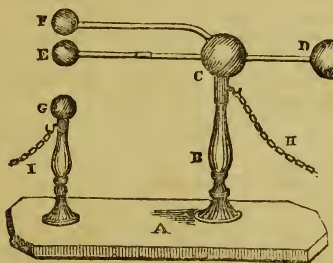


BALANCE DISCHARGER.

For discharging a battery at a certain degree of intensity an instrument is sometimes used, in which electric repulsion is the acting principle. This is represented beneath :—

A is a foot-board, supporting two glass pillars B and G. C is a brass ball and socket, fitting upon B, and by a hook attached to it holding the chain H. The ball C bears at top a brass arm and ball F, which are fixed immoveably to it. Upon an axis running through C is supported the balance D E also of metal. In order that this balance may play up and down so that E shall be able to reach and fall upon G, a slot or long aperture is made on two opposite sides of C, wide enough for the wire to pass readily. There is also a chain attached to

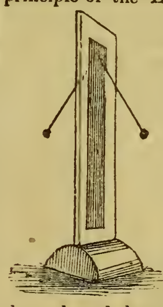
the socket of G, marked I; and a small moving weight between C and E to be slipped backwards and forward, as required. To understand the mode of action of this valuable discharger, it is to be remembered that bodies when electrified similarly repel each other in proportion to the degree of their electrization. Now connect H with the inner part of the battery, and I with the outer, and see that the balance is loaded a little, by moving the small sliding weight between C and E. The brass part of the balance connected with H will become charged, and when sufficiently charged to overcome the balance weight, the ball E will be repelled downwards, and fall to G; as this is connected with the outside of the battery it will be discharged by the contact of G and E. It is to be remarked that while repulsion will go on between F and E attraction will arise between E and G, therefore there is a double force to drive down E.



Explanation of the shock.—The explanation given of the phenomena of the Leyden jar is that of *induction.* Glass is supposed to contain, at all times, on its two surfaces, a large quantity of the electric fluid, which is so disposed that if you increase the quantity on one side the other must throw off an equal proportion; or, when one side is positive, the other must be negative. Now, as no more of the electric fluid can be forced on one side than can go off on the other, there is no more in the bottle after it is charged than there was before; the quantity is neither increased or lessened on the whole, though a change may be made in its place and situation; *i. e.* we may throw an additional quantity on one of its sides, if, at the same time, an equal quantity can escape from the other, and not otherwise. This change is effected by lining parts of its two surfaces with a non-electric, through the mediation of which we are enabled to convey the electric fire to every physical point of the surface we propose to charge, where it exerts its activity in repelling the electric particles naturally belonging to the other side; all of which have an opportunity of escaping by the lining in contact with this surface, which, for that purpose, must communicate with the earth. When the whole quantity belonging to this surface has been discharged, in consequence of an equal quantity thrown upon the other surface, the bottle is charged as much as it can possibly be. The two surfaces are at this time in a state of violence; the inner, or positive side, strongly disposed to part with its additional fire, and the outer or negative side, equally desirous to attract what it has lost; but neither of them capable of having a change in its state effected, without the equal and contemporary participation of the other. That notwithstanding the vicinity of these two surfaces, and the strong disposition of the electric fluid contained in one of them, to communicate its super-abundance to the other, and of that to receive it, yet there is an impenetrable barrier between them; for, so impermeable is glass to the electric fluid, (though it permits one side of it to act on the other,) that its two surfaces remain in this state of contrariety till a communication is formed between them, by a proper conductor, when the equilibrium is suddenly and violently restored, and the electric fluid recovers its original state of equality on the two sides of the glass.

We shall be able to prove the truth or error of this reasoning by the following experiments.

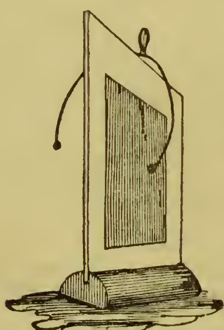
252. *To charge a sheet of glass.*—The principle of the Leyden phial is seen very perfectly in a sheet of glass, such as is represented. Tin-foil is to be pasted on each side, to within an inch or more of the edge; fasten a thread, holding a pith ball, to the tin-foil on each side with a piece of wax; connect one coating with the ground, and touch the prime conductor with the other, the plate of glass will be charged, and the pith balls fly out to some distance; connect the two sides together with a wire, the shock will pass, and the pith balls will become at rest.



253. *Magic picture.*—Procure a frame of dry wood, and furnish it with a glass, as a picture-frame usually is, cover this with tin-foil, as in *Ex.* 252; cover the back with a loose piece of dark paper, or a thick dry pasteboard, cutting a small hole in the middle, in order to bring through it a strap of tin-foil, which is pasted upon the coating of the under side of the glass, and reaches to the frame; now cover the tin-foil on the face of the glass with a picture of any kind, and the instrument is complete. To use it, put a

piece of money on the picture, and holding it by the frame where the tin-foil is, charge the picture by presenting a ball from the conductor to the money. When charged, take hold of the frame by the other hand, at some other part of the frame, and direct another person to hold that part which you have just quitted with one hand, and to take off the money with the other. His attempt to do so will discharge the sheet of glass, and he will receive a shock in the fingers, while he will be quite unable to take off the money. This amusing apparatus is represented in the following cut :—

254. *Electric pendulum.*— Construct an instrument of wire, with pith balls at the end of it, as represented. Hang this on the charged plate of glass, when it will vibrate, so that its balls touch each side alternately, and finally discharge the jar.



A charged jar may be handled with impunity, provided we are careful never to touch the outside and inside of it at the same time, as may be easily proved.

255. *To discharge a iar gradually with the finger.* — First, put the jar on an insulating stand, then touch the outer and inner coating alternately with the finger, and a small spark will pass each time, and finally discharge the jar.

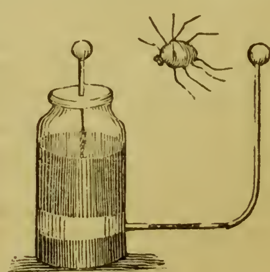
256. *To wipe out a jar when charged.*— Insulate the jar on a glass legged stool, being careful not to touch the stool or outside coating, either with your hand or clothing. Take off the cover by the ball, only a small spark will pass to the finger ; holding a handkerchief in your hand, dip your hand carefully into the jar, wipe it out with the handkerchief, and draw it carefully out again. then put on the cover as at first. Now discharge the jar in the usual way with the discharger, and you will find that although it has been thus handled, yet you neither received any shock in wiping it out, nor was the fluid silently dissipated.

257. *To show that an insulated jar cannot be charged.*—Screw a Leyden phial, whose coating is free from points, upon an insulated stand, and place it so that its knob may be in contact with the conductor, (taking care that no conducting substance is near the coating of the jar,) turn the cylinder round a sufficient number of times to charge the phial, then examine it with a discharging rod, and you will find it had received no charge ; which shows clearly, that except the electric fluid can escape from one side of the jar, it can receive none on the other.

258. *To charge a jar negatively.*—Insulate two Leyden bottles ; let their coatings be in contact, and while you charge the inside of one positively, let a person, standing on the floor, touch the top of the other with his finger, and it will be charged negatively.

259. *To discharge a jar silently.*—Procure a Leyden jar, which has a hole in the top of the ball, charge it, insulate it, then screw a pointed wire on to the ball. This will soon discharge the jar silently ; or the orrery or flyer formerly described may be substituted for it.

260. *Electrical spider.*—Make an object in the shape of a spider—its body of cork, with eight legs of white thread, about an inch



long, and suspend it by a thick black silk thread. This will play between the knobs of two phials, if one be electrified positively, and the other negatively; or will discharge a phial, if suspended at a equal distance from the knob at the top, and a knobbed wire proceeding from the bottom of it.

261. Let a coated jar be set on an insulating stand, and let its knob be touched by the knob of another jar negatively electrified; a small spark will be seen between them, and *both* sides of the insulated jar will be instanly negatively electrified.

262. Fasten a pith ball electrometer by a little wax to the outside coating of a jar, slightly charge it with positive electricity, and set it on an insulated stand, the ball will either not diverge, or only a very little; bring the knob of a jar which is strongly charged with positive electricity, near the knob of the former, and the balls will diverge with positive electricity.

263. Let the same jar, with the pith balls affixed to its outer coating, be slightly charged negatively and then insulated; bring the knob of a jar, which is strongly electrified negatively, to that of the insulated one, and the pith balls will diverge with negative electricity.

264. Charge a jar positively, and then insulate it; charge another strongly with negative electricity, bring the knob of the negative jar near that of the positive one, and a thread will pass between them; but when the knobs touch each other, the threads after being attracted will be repelled by both.

These experiments seem to show that the negative electricity is sometimes superinduced on the positive, and for a few minutes after they are separated both will appear negatively electrified, but if the finger is brought near the knob of that jar on which the negative electricity was superinduced, it will instantly be dissipated; a small spark will strike the finger, and the jar will be charged positively as at first.

265. *To charge a jar by its own fluid.*—Let the rubber, and also the prime conductor of an electrical machine, be both insulated. Connect the inside of a Leyden jar which is also insulated with the prime conductor, and the outside of the same wire with the cushion. Upon turning the handle, the phial will become charged on the inside by the same fluid which is taken from the outside.

266. Take two equal jars, with a quadrant electrometer attached to the knob of each. Place one of them in contact with the positive conductor of the machine, and the other with the negative conductor. When the machine is turned both jars will charge, and to the same height, as may be seen by the receding index of each electrometer. Remove the jars from the machine, and place them on two separate insulating stands; connect their knobs by an insulating or glass-handled discharging rod. No explosion will ensue, although they are oppositely electrified; for their electricities depend on the attraction of their outer surfaces, which in this insulated state have no means of communication. Connect the outer surfaces by a wire or other conductor, and repeat the experiment—an explosion will take place, and both jars will be discharged

267. Hold a clean and dry pane of glass by one corner, and pass it before a ball connected with the prime conductor of the machine, so that the ball may successively come in contact with every part of the middle of the pane of glass, whilst the finger or any uninsulated substance is opposed to it on the opposite surface; by this process the glass will be charged. Apply the discharging rod to the opposite surfaces; an explosion will ensue. Make the contact with the discharging rod again in another part of the surface—another explosion will be procured; and in this way many are sometimes obtained in succession.

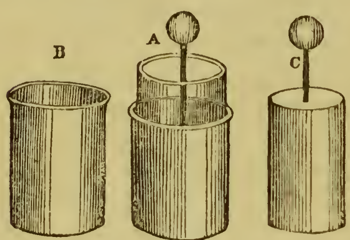
268. Repeat the experiment of charging the pane, and then place it between two plates of metal of about half its size. On the application of the discharging rod, but one explosion will be procured, but it will be louder and more brilliant than those procured from the uncoated pane. Hence it is seen that the use of the metallic coating is to connect the effects of every portion of the surface of the jar, so that it may be charged or discharged by the simple applition of the machine or discharging rod to one portion of its surface

269. Place an uncoated jar beneath the conductor of the machine, and suspend a chain from the conductor so as to hang in the centre of the jar; on turning the machine the chain will move round, and apply itself in succession to every part of the internal surface of the jar, which by that means receives a charge. Apply the discharging rod, and the chain will return over the parts with which it has been in contact, and thus by a few of its revolutions the jar will be discharged.

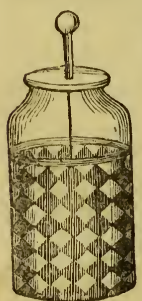
270. Take a Leyden jar, coated on the inside as usual, but with a coating of only 1 inch high on the outside; during the charge and discharge of this jar ramifications of electrical light will be seen on the outside.

271. *Jars with moveable coatings.*—Procure a jar, with a double set of moveable tin coatings, either of which may be adapted to

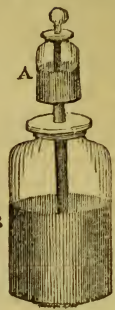
it at pleasure, the outer coating being a tin case large enough to admit the jar easily within it, and the inner coating a similar case sufficiently small to pass readily in the inside of the jar. The charging wire of the inner coating should be surrounded by a glass tube covered with sealing wax, to serve as an insulating handle, by which the inner coating may be lifted from the jar when that is charged without communicating a shock to the operator. Arrange the jar with its coatings, and charge it, it will act in every respect as an ordinary coated jar; charge the jar, and without discharging it, remove the inner coating by its insulating handle. If this coating, when removed, be examined, it will be found not at all, or but slightly electrified; lift the jar carefully from within its outer coating, and examine that—it also will evince no sign of electricity. Fit the jar up with the other pair of moveable coatings, that have not been electrified, and apply the discharging rod; an explosion and spark will ensue, proving that the coatings are only the conducting materials from one side of the glass to the other, and that it is the glass itself on which the fluid is accumulated. The following cut shows the usual form of these jars:—



272. *Diamond jar.*—Take a bottle, whose exterior coating is formed of small pieces of tin-foil, placed at a little distance from each other. Charge this bottle in the usual manner, and strong sparks of electricity will pass from one spot of tin-foil to the other, in a variety of directions; the separation of the tin-foil making the passage of the fluid from the outside to the table visible. Discharge this bottle by bringing a pointed wire gradually near the knob, and the uncoated part of the glass between the spots will be pleasingly illuminated, and the noise will resemble that of small fired crackers. If the jar is discharged suddenly, the whole outside surface appears illuminated. To produce these appearances the glass must be very dry.



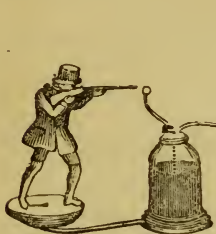
273. *The double jar.*—This instrument is seen in the margin. It is used for various experiments, and shows how necessary it is to connect the outside and inside of the same jar together, before it will be discharged. Place the double bottle on a table not insulated, and charge the upper bottle A positively by connecting its ball with the conductor. The outside of A therefore, and also the inside of B will be negative, and the outside of B positive. Now connect by the discharging rod the outer coating of B with the inner coating of A, and no shock will pass between them. Again, connect the outside of B with the inside of B, and a shock will pass. Now connect the inside of A with the inside of B, and a second shock will be obtained. A series of bottles may thus be arranged, and a series of shocks obtained by one charge only.



274. *To convey a shock to a distance.*—Amusement is often excited by giving a person a small shock unexpectedly. This may be done easily by a small Leyden jar holding about half a pint. It may be held in the hand of the operator, without danger, by its outer coating, he holding at the same time a chain connected with the coating. The other hand should hold a glass handled discharging rod, connected with the other end of the chain. If he touches a person with the ball of the discharging rod, and also with the knob of the small charged phial, a shock will pass along the chain, and through the person, without affecting the operator. It is usual to employ for the above purpose a *coated director*, which is a Leyden jar, made of the following form, and coated in the ordinary manner.

275. *The electrical sportsman.*—This experiment is to illustrate the fact that a jar will be liable to discharge itself when the two coatings are too close to each other. The inner coating of the Leyden jar is connected with two wires; one of which proceeds to the birds—the other proceeds to within a short distance of the muzzle of the gun. The birds are made of small bits of pith, with a portion of feathers to each to represent wings. They are attached to pieces of linen thread, 4 or 5 inches long. The gun is connected with the outer coating of the wire proceeding from it to the figure,

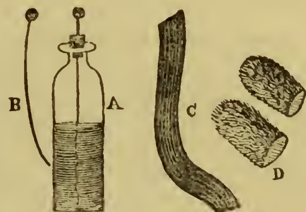
and a slip of tin-foil which is pasted along the figure to the muzzle. Connecting the wire with the electrical machine in action it will of course become charged, during which time the birds will elevate themselves by electrical repulsion; when the bottle is charged to a certain extent, the distance between the muzzle of the gun and ball near it will not be sufficient to restrain the passage of the fluid, which will therefore pass between them, occasioning at the same time a flash of light, a loud report, and the falling of the birds.



276. *Cavallo's self-charging Leyden jar.*—Take a glass tube of about 18 inches in length, and an inch or an inch and half diameter. It is immaterial whether one of its ends be closed or not. Coat the inside of it with tin-foil, but only from one open extremity of it to about the middle; the other part remaining uncoated. Put a cork in at the coated end, and let a knobbed wire pass through the cork, and come in contact with the coating. The instrument being thus prepared, hold it in one hand by the naked part, and with the other hand dry rub the outside of the coated part of the tube, but after every three or four strokes you must remove the rubbing hand, and touch the knob of the wire, and in so doing a little spark will be drawn from it. By this means the coated end of the tube will gradually acquire a charge, which may be increased to a considerable degree. If then you grasp the outside of the coated end of the tube with one hand, and touch the knob of the wire with the other, you will obtain a shock, &c. In this experiment the coated part of the tube answers the double office of electrical machine, and of Leyden phial.

277. Instead of a tube this instrument may be constructed with a pane of glass, in which case it will be rather simpler, but it cannot be managed so easily, nor yet charged so high as the tube. A piece of tin-foil must be pasted only on one surface of the pane, leaving about 2½ inches or 3 inches of uncoated glass all round. This done, hold the glass by a corner, with the coated side from you, and with the other hand rub its uncoated side, and take the spark from the tin-foil alternately, until you think that the glass may be sufficiently charged; then lay the glass with its uncoated side flat upon one open hand, and on touching the tin-foil with the other hand you will receive the shock.

Adams's portable jar.—Mr. Adams, an optician of the last century, invented the following simple apparatus, whereby a shock may be procured without the aid of an electrical machine. A is the small Leyden phial or jar that holds a charge. B is a bent wire to discharge the jar. C is a varnished ribbon to be excited, and communicate its electricity to the jar. D are two hare or other skin rubbers, which are to be placed on the first and middle fingers of the left hand.



278. *To charge the jar.*—Place the two finger caps D on the proper fingers; hold the jar A at the same time at the edge of the coating on the outside, between the thumb and first finger of the hand; then take the ribbon in your right hand, and steadily and gently draw it between the two ribbons D on the two fingers, taking care at the same time that the brass ball of the jar is kept nearly close to the ribbon, while it is passing through the fingers. By repeating this operation thirteen or fourteen times the electrical fire will pass into the jar, which will become charged, and by placing the discharger C against it, as shown in the figure, you will see a sensible spark pass from the ball of the jar to that of the discharger. If the apparatus is dry, and in good order, you will hear the crackling of the sparks when the ribbon is passing through the fingers, and the jar will discharge at about the distance of ½ an inch from the balls.

279. *To electrify a door knob, &c.*—We often hear of persons electrifying the handles of doors, the pulls of bells, &c., yet this is a very difficult experiment to manage. First there must be a Leyden jar in readiness, and this must be kept charged, which of itself is difficult, then the outside of the jar must have a wire connected with it, which reaches under the carpet or otherwise, so as to be concealed beneath a person's feet, when

standing at the electrified door, a circumstance almost impossible if in the street, and not always easy of accomplishment in a room. It is absolutely necessary that this wire should be trodden upon by the person to be shocked. The knob, knocker, or bell pull of the door should be furnished with a second wire, coming near to the ball of the inside of the charged bottle, but not so near as to draw off the fluid. It must be placed so that when the knob is turned, the knocker lifted or the bell pulled, this wire may come within striking distance of the bottle, which will consequently be discharged. The fluid passing along the wire, the knob to his hand, his body, and finally the wire beneath his feet to the outside of the bottle, when the circuit will be of course complete.

CHAP. IX.

MECHANICAL, CHEMICAL, AND MAGNETIC EFFECTS.

The following experiments show the effects of the electric fluid when thrown against, or passing through various substances, some of which it displaces, others illuminates, others inflames, and a fourth kind of objects it rends to atoms in its passage. Many of these effects induce us to attribute a material character to the electric fluid, and to believe that it is a substance, imponderable as far as we know, as are light and heat, yet nevertheless a matter rather than a power ; not like gravitation, and the centrifugal force, powers of nature, but, like air, one of its solid but subtle elements, the occasion of numerous luminous phenomena of common occurrence, and therefore considered by the ancients as elemental fire :—whether it be so, present knowledge seems to confirm rather than to deny. Professor Faraday, and other philosophers of equal learning, hold this opinion, and believe that heat and electricity are but modifications of each other. In some respects their effects are identical, as many of the experiments of the present chapter will show ; in other respects they appear perfectly distinct.

1. Fire will inflame combustible substances, so will electricity.
2. Heat is produced by friction, so is electricity.
3. The best conductors of heat are mostly also the best conductors of electricity.
4. Metals are melted by heat and also by electricity. On the contrary, it is alleged, Firstly, that the electric fluid has a strong scent which simple heat has not. Secondly, an increase of heat produces an increase of fluidity ; but bodies charged positively are not thereby rendered fluid. So also, thirdly, a deprivation of the electric matter which a substance may contain does not cause the same congelation as that occasioned by abstracting caloric from it. Fourthly, caloric not only heats but expands bodies, the electric fluid does not produce this effect ; however long a body may be electrified, it neither becomes hotter to the touch, nor more extended in dimensions. Fifthly, nothing analogous to the nature of electrical attraction or repulsion can be discovered in heat.

It is said by those who deny the materiality of the electric fluid that it is only the agitation of the air which produces its various effects, and that the compression of the air causes those ignitions by the fluid, which we shall presently allude to. To confute this opinion by positive experiment may be difficult, yet an appeal to the reason will soon show the incorrectness of the opinion ; look at the lightning, and then say can this mighty phe-

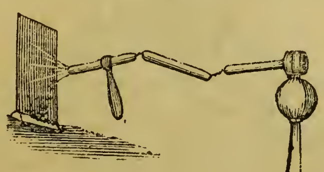
nomenon be occasioned by any compression of the air which the mind can conceive. Even supposing that the air would be thus compressed, how immense must be the power which could thus compress it, and what is this power but the electric fluid. Besides this, electrical appearances can be produced in a vacuum; the motion of the fluid, also, is inconceivably more rapid than the quickest motion of the air that we are acquainted with.

We shall endeavour to show that in some of the experiments the air is scarcely condensed at all, and would not produce the effect if it were. If the air were condensed, as the fluid passes from the positive to the negative side of the apparatus, it would be condensed at that point only; or if we suppose two electric fluids, rushing towards and meeting each other, the concussion, and consequently the condensation, could only take place at some point near to the extreme end, neither of which appear to be the case, as in whatever manner the experiments may be varied, there does not appear to be any reason to think that the inflammation takes place at any one point of the interrupted circuit rather than at any other point. Besides which, when the inflammation of air and hydrogen gas take place, the interruption of the circuit is extremely minute, and the air in a much less quantity, so as to diminish very much the probability of this assumption.

These remarks and the experiments which illustrate them, clearly show that the electrical fluid is different in its nature from those elements with which it alone can be compared; we are therefore bound until knowledge shall so progress as to explain more fully the kingdom of nature to consider the electric fluid as a material body, imponderable, and with properties peculiarly its own. The following experiments will afford much amusement and instruction.

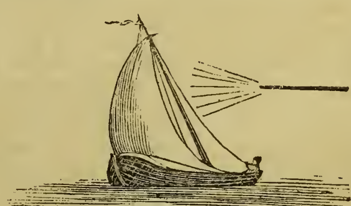
Ex. 280. Stand a card upright upon a table, by a little narrow foot made of cork so that but a slight force is necessary to overturn it. Hold towards one side of this a point connected with the prime conductor of a machine. The breeze passing from the point will blow down the card.

For experiments of this kind it is most convenient to use a flexible tube, this is a tin or brass tube, furnished at one end with a joint and socket to fit into one of the holes of the prime conductor, and at the other with a screw, upon which may be fastened either a ball or a point as different experiments require. It is made usually of three joints connected together by a piece of chain covered with silk. The joint which bears the ball or point, bears a glass handle; so that a person taking hold of this may move the point about as he pleases, without destroying its insulation. The following shows this convenient instrument, which is used for many other purposes in electricity. The joints may be 15 inches long each.



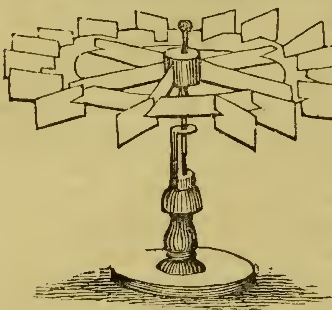
281. The card instead of being supported upon a stand, may be suspended by a fine wire, or a linen thread from the ceiling, when according to the strength of the fluid the card will be repelled.

282. *Electrical boat.*—Hold the charged point towards the sails of a small vessel floating in a basin of water. The impact of the fluid against the sail, occasions the vessel to float away from it. The sail should be of white paper.

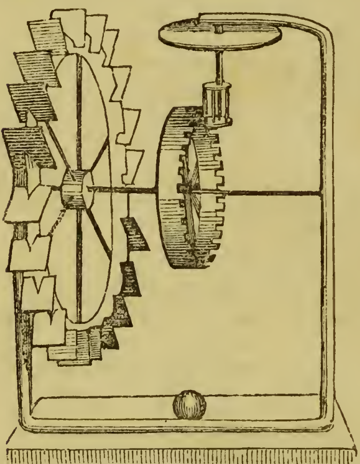


283. *Electrical vane.*—Make a vane or wheel of paper, or thin pasteboard, (such as is represented annexed) and suspend it by a pin upon a piece of brass at the centre. Hold the positive charged point towards one side

of it, and opposite the floats, when the wheel will be put into rapid rotatory motion.



The wheel may be suspended vertically, instead of horizontally, and a system of wheel-work put in motion by the same means. Several of these contrivances were invented by Mr. Ferguson, one of which is represented beneath :—

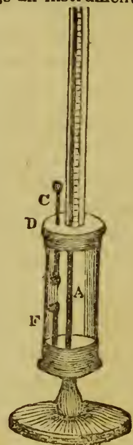


284. Fill a very small, thin glass tube with water, pass a strong shock through it, the expansion of the water, occasioned by the passage of the fluid, will burst the tube and scatter the water. This is a pretty experiment if the tube is fitted up to a hulk, as a mast. The shock would then represent a flash of lightning, the mast would be struck, and the rigging fall overboard, while by adding one of the other experiments afterwards described, the hulk may be made to take fire.

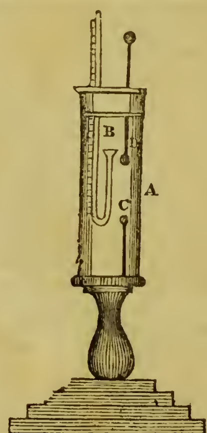
285. *Water expanded.*—Discharge a battery through a drop of water, previously placed on the knob of one of its bottles ; the whole will be instantly exploded into vapor. The sparks will be much longer than common, and more compact.

286. *Quicksilver dissipated.* — Send a discharge to a greater or less distance through one or more drops of quicksilver, the discharge diffuses itself into a fine spray, and drives the drops into vapor ; part of it rising into the air as smoke, the other part remaining on the glass.

287. *Kinnersley's air thermometer.*—This is an instrument for showing the expansion



of air when an electrical shock is passed through the instrument. A is a glass tube, upon both ends of which a brass cap is cemented. B a thermometer open at both ends, and with a scale attached to the back. This tube passes through the upper brass cap, and nearly reaches the bottom of the under cap. F is a brass ball and wire cemented to the under cap, a similar sliding ball and wire C passes air tight through a collar of leather on the upper cap, so that its ball may be placed at different distances from the ball of the fixed wire F. The plate of the upper cap is made to unscrew, so that colored water may be put in previous to the performance of the experiment. By the rising of the water in the thermometer tube over the scale above the result of the experiment is seen.

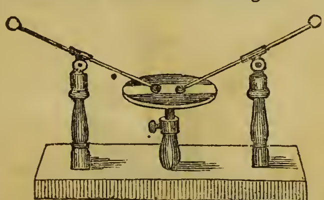


288. *Coward's electrical air thermometer.* —This instrument, a cut of which is seen above, differs but little from Kinnersley's It is however more convenient in use. A is the glass tube. C and D the balls for the shock to pass, and B the thermometer tube,

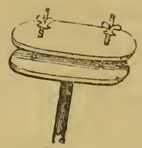
and which is bent upwards at the lower part. Previous to using the instrument, fill the tube B to the height of about 2 inches with a colored fluid; on the surface of which in the long arm is to rest a light guage made of quill, part being cut so as to act as a spring, which will hold it at any part of the tube.

289. To show the expansion of the air by either of these instruments, pass a shock from one ball to the other; in consequence of this the fluid will be driven up the tube. To see to what extent, Mr. Kinnersley's electrometer must be viewed at the time, but as in Mr. Coward's the spring quill guage will retain the position to which it has been driven, this instrument may be inspected whenever convenient.

290. *Henley's universal discharger*, for performing numerous electrical experiments, it is necessary to use an instrument like the following, which consists of a rectangular wooden foot, upon the middle of which rises a short wooden pillar, with a screw on the side of it. Into this fits a shank, bearing a small table 4 or 5 inches in diameter, upon the top of the table is let in a piece of ivory, which it will be observed is a non-conductor. The side pillars shown are of glass, except at the top, where is fastened a metallic cap, with a universal or ball and socket joint, or some other joint which allows an equable motion in every direction, to a short horizontal socket above. Wires 6 or 8 inches long pass through these sockets. Their outer ends are terminated by rings, their inner ends are blunt points, but covered with balls which slip off and on. Thus by the construction of the instrument, the balls may be supplanted by points, and both one and the other placed at any distance from each other that may be desired. If one of the rings or wires be connected with the outside of a Leyden jar or battery, and the other wire attached to one end of a discharging rod, when the discharge of the jar or battery is made, the shock will pass through whatever substance is placed between or upon the balls of the universal discharger.

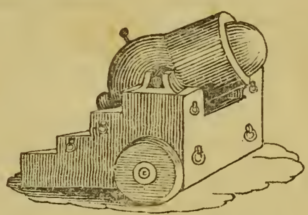


The table is in some experiments taken away, and a small press put in its place. This press is formed of two pieces of baked wood, about 4 inches long and 2 wide;



the lower one fixed on a shank that fits the centre socket of the discharger, and the upper one connected to the lower by two thumb screws, as shown in the cut, so that any thing placed between the boards of the press may be held there securely while a shock is sent through it.

291. *Electrical bomb.*—The next figure represents the electrical bomb, the firing of which, if firing it can be called, where no fire is, is accomplished by a strong shock of a large Leyden phial or battery sent through it. The bomb is made of ivory, with a small short bore in it, so formed that the ball, which may be of ivory or cork, can be imbedded a trifle more than one half in the bomb, and a cavity of a smaller size be behind it, with two wires entering this small cavity. When a strong shock is passed through these wires, the air withinside will be agitated, and throw out the ball.



292. Fill the cavity or chamber behind the ball with two or three drops of water, pass the shock through, and the expansion of the water will be so great as to throw out the ball with greater force than before.

293. *Paper rent.*—Rest upon the table of the discharger a piece of white paper, 4 or 5 inches square, and placing the balls about 2 inches from each other, send a shock along the surface of the paper, when it will be rent in pieces along the line which the fluid travels.

294. *To fracture sugar.*—Place between the two balls of the discharger a small lump of sugar, and send a shock through it; the sugar will most likely be broken; if not, send a second and a third shock through it, when, unless the shocks have been very small, or the lump very large, it will be broken into many pieces. If this experiment be performed in the dark, the sugar will give out at the time of the shock, and for half a minute afterwards, a strong phosphoric light.

295. *To pierce a card.*—Pass a shock through a card, by placing the balls of the discharger on each side of and close to the card, a minute hole will be pierced through

the card, and what is very singular a *burr* or projecting edge will be formed on each side of the card. A shock may be passed through three or four cards at once, and each have its double burr.

296. Hang to the ceiling four or five sheets of brown paper, and pass a shock through them, the whole of the paper will be pierced without being in the slightest degree moved. Upon smelling the part of the paper which has been pierced, it will be found to have imbibed a strong odour analogous to that of phosphorus.

297. Either of the above experiments, and indeed most others may be performed without the aid of the universal discharger; for example, if a few cards or sheets of paper be held against the outside of a Leyden jar, and one of the knobs placed close to the paper, while the other knob approaches the inside of the jar, the charge will pass and pierce the cards.

298. Introduce two wires into a piece of soft pipe clay, and pass a strong shock through them; the clay will be curiously expanded in the interval between the wires. The experiment will not be successful if the clay be too moist or too dry.

299. *Splintering wood.*—Drill two holes in the opposite ends of a piece of wood, which is ½ an inch long, and ¼ of an inch thick; insert two wires in the holes, so that their ends within the wood may be rather less than ¼ of an inch distant from each other. Pass a strong charge through the wires, and the wood will be split with violence.

300. *Coin stuck to a jar.*—Charge a large jar, and place a shilling or other piece of coin between the knob of the discharger and the coating of the jar.

301. Charge a very large jar, connect its outside with one that is ten or twelve times smaller, make a communication between their inner coatings with the discharging rod, and the small jar will be broken, the quantity o. electricity transferred to it being beyond the proportion of its size.

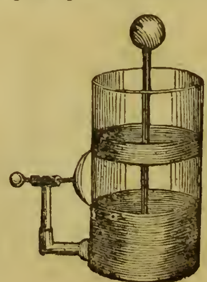
DIRECTION OF THE FLUID.

The mechanical effects of electricity have been employed to indicate the course of the electric fluid in the discharge, and thus to confirm the proposition that assumes positive electricity to be an accumulation of electric fluid, and negative electricity to be a deficiency, in opposition to the hypothesis first proposed by Du Faye, that positive and negative are two distinct electric powers.

302. The direction of the electric fluid is rendered visible when a Leyden jar, which has been rendered slightly damp by breathing on it, is placed with its knob in contact with the positive conductor of the machine in a darkened room. When the jar is fully charged, if the turning of the machine be continued, the electric fluid will be seen to pass from the inner to the outer coating over the uncoated interval in luminous streams, producing an effect similar to that of water overflowing from the top of a vessel that is kept constantly supplied. If the jar be removed, and its knob placed against the negative conductor, the stream, when the jar is overcharged, will evidently pass in a contrary direction, that is from the outer to the inner coating. A certain degree of dampness is necessary in this experiment, to prevent the discharge of the jar by spontaneous explosion, in which case the fluid passes too rapidly from one surface to the other to admit the ascertainment of its direction. If the moisture be not sufficient, divergent brushes of light pass from the positive to the negative surface at intervals, instead of the continuous streams before described.

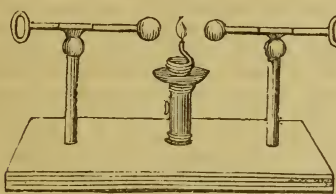
303. *Discharge by withdrawing atmospheric pressure.*—Place a charged jar on a small glass stand under the receiver of an air pump. As the receiver is exhausting, the electric fire will issue from the wire of the jar in a very luminous pencil of rays, and continue flashing to the coating till the air is exhausted, when the jar will be found to be discharged. The direction of the rays of light will have the appearance of tending to or verging from the jar, according as it is charged positively or negatively.

304. *The belted bottle.*—This instrument shows the passage of the fluid during the charging of the bottle, and is but a modification of the last experiment. The coating both inside and outside is put on as represented. The belt on the outside is only put in contact with the lower part of the coating by means of the sliding piece on the outside. The wire within is attached to the inside of the bottom. In charging, the lower part becomes charged first, and the fluid will be seen to pass upwards inside in flashes, while

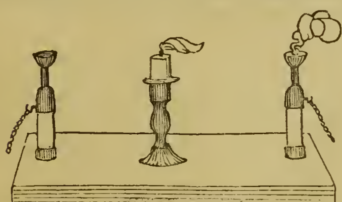


if the connecting piece be withdrawn, the fluid will be seen to pass downwards on the outside from the belt to the lower part.

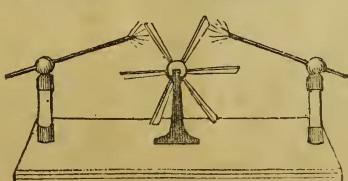
305. Place a lighted taper between the wires of the universal discharger, they being 4 inches apart, and the flame midway between them. Connect the coating of a small charged jar with one wire, and bring its knob in contact with the other; if the charge be just sufficient to pass the interval without explosion, the flame of the taper will be constantly blown from the positive wire to that which is negative.



306. Construct an apparatus, such as is represented beneath. There being a small metal cup at each side, supported by a glass rod, and a lighted candle in the middle between them. Into each cup put a small piece of phosphorus—connect one chain with the prime conductor, and the other with the cushion. Turn the machine, and the fluid will pass from the positive cup to the lighted wick, and driving this forwards against the opposite cup will soon heat it so as to fire the phosphorus, while there will appear no emanation of the fluid from the negative cup.

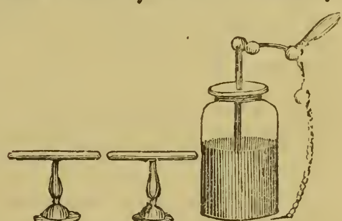


307. The next figure represents an apparatus similar to the last, except that it has wires instead of cups, and a light vertical wheel in the centre. Upon connecting the wires with the different parts of the machine, and putting it in motion, the wheel will turn from the positive to the negative side.



308. Lay two straight sticks of sealing wax on the table of the discharger parallel to each other, so that the juncture of their rounded edges may form a groove; on this a large pith ball is to be placed, and the wires of the discharger are to be arranged with their points in the direction of the groove, and at 4 inches from each other, the ball being equally distant from both. On passing a small charge from one wire to the other, the ball will be driven from the positive to the negative; and this effect will be constant if the terminations of the wires are pointed, which they should be for these experiments of transmission. If blunted wires be employed, the ball will frequently vibrate between them, and apparently render the result equivocal.

309. *Lateral discharge.*—The following cut represents a small conductor insulated, and nearly touching a charged jar. There is a second conductor, also insulated and nearly touching the former, and in a straight line with it. Make the discharge by a discharging rod, from which a chain hangs that does not touch the bottom of the jar, and the farther conductor will receive an electric spark, which quits it again almost at the same instant. This electrical appearance without the circuit of an electrical jar is called the lateral explosion. This may be tried in other ways.



310. Place on a dry board a little bran or other light matter, and lay along it a wire which forms part of a discharging circuit for a large jar or battery. Upon making the discharge, the bran will be scattered from its place by the lateral explosion, and the greater the force of the explosion, so much the greater of course will be the scattering. It is not surprising therefore, that heavy bodies should be removed to considerable distances by a strong flash of lightning. Dr. Priestly imagined that this lateral explosion was produced by the explosion of the air from the place through which the electric discharge passes. This lateral force is not only exerted in the neighbourhood of an explosion, when it is made between pieces of metal in the open air, but also when it is transmitted through pieces of wire that are not thick enough to conduct it properly. The smaller the wire is and the stronger the charge, the

greater is the dispersion of light bodies near it. The following are examples of lateral explosion.

311. Discharge a Leyden jar by means of a common wire discharging rod, or one which has no glass handle to it. Holding the wire firmly, no sensation, or very little will be felt in the hand, but hold it very lightly and discharge the jar a second time, and a very disagreeable trembling of the fingers will be felt, owing to the action of the fluid laterally. The same is the case when a spark is taken from the prime conductor by a ball and wire held loosely in the hand, though no sensation is felt when the wire of the ball is grasped firmly.

312. Let two wires be fitted into a groove on the surface of a piece of smooth mahogany, ivory or sealing wax, in such a manner that by sliding the wires backwards or forwards, their ends may be placed at any required distance from each other. When they are about ½ an inch apart, place a thumb or finger over the interval, and pass a charge from wire to wire; the thumb will appear perfectly transparent during the passage of the spark beneath it, but no unpleasant sensation will be felt.

313. Substitute a jar of water or any colored fluid, in the place of the thumb; when the discharge is made, the fluid will be distinctly and curiously illuminated.

314. Place the ends of the wires at the distance of ¾ of an inch, and over the interval lay a thick piece of pipe-clay or of pumice stone; when the charge passes, these opaque substances will appear perfectly transparent.

The light of the electric fluid in passing through an interval of air near to or in the middle of a semi-transparent body, or one which becomes luminous by the influence of an intense degree of ordinary light, communicates to it a luminous appearance sometimes of some lengthened duration.

315. *Phosphoric vapors.*—Put a piece of common phosphorus on the point of a wire which hangs from the prime conductor of a machine. Until the machine is turned, the vapors will ascend, but when the conductor and wire are electrified, supposing the wire hanging in the same position, the vapors are carried downwards, and form a very long cone of electric light, which is seen perfectly distinct from it. When the electrization is discontinued, the vapors ascend as at first.

316. *Phosphorus inflamed.*—Place a piece of phosphorus, as in the last experiment, or in any other way projecting from the prime conductor, and by means of a metallic ball held in the hand take a spark from it. This will inflame the phosphorus. A ball for all such purposes as this should have a wire handle to it, the wire being grasped, and the ball held beyond the hand.

317. *Candle re-lighted.*—Instead of the phosphorus, in the last experiment, substitute a candle, the flame of which has just been blown out, and which has a long snuff; upon passing a shock or spark through the incandescent part of the wick, the candle will be re-lighted.

318. *Canton's phosphorus illuminated.*—Take some of the powder of Canton's phosphorus, and by means of a little spirits of wine stick it all over the inside of a clean glass phial, then stop the phial, and keep it from the light. To illuminate this phosphorus, draw several strong sparks from the conductor, keeping the phial about 2 or 3 inches from the sparks, so that it may be exposed to their light; the phial will afterwards appear luminous, and remain so for a considerable time.

319. Cut out in pasteboard, or soft wood, the figure of a crescent or any of the planets; cover this equally with the white of an egg, beat up till it is quite smooth, over which sift the phosphorus through a fine lawn sieve, then let it dry, and blow off all that is not fixed by the egg. To make the experiment, place the object in the communication between two directors, and discharge the jar, when the whole will become beautifully luminous; care must, however, be taken to hold the directors at a little distance above the phosphorus, for if it passes through it, the whole of the powder in the track of the fluid will be torn off.

320. Place a small key on the phosphorus, and discharge a Leyden phial over the phosphorus, and then throw the key off from it, and when it is exhibited in the dark the form of the key and all its wards will be perfectly seen.

321. Place a piece of dry chalk on the table of the universal discharger, and adjust the wires on its surface, with their ends at 1 inch distance from each other. Pass a strong charge from wire to wire, and after the explosion a streak of light will be evident in the track of the discharge. It will continue luminous for several seconds.

322. Place upon or within a brisk fire, a few oyster shells, and calcine them until they cease to emit smoke, and appear burnt through; this may be from a quarter of an hour to two hours, according to the strength of the fire and compactness of the shells. Many of them will exhibit the prismatic colors when exposed to the light of the sun. Mr. Wilson excited some of these shells by electricity as follows:—

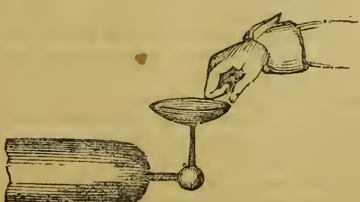
323. *Prismatic illumination.*—Mr. Wilson placed upon a metal stand, which was rounded at top, and about ½ an inch in diameter, a prepared shell, and near the middle, where the color-making parts predominated, he brought the ends of a metal rod, and then connected the two metals properly with the coatings of a charged phial, in order to discharge the fluid. In this circuit there was left, designedly, an interval of about 3 inches, unoccupied by metal, and next one side of the glass. The discharge was made by completing the circuit with metal where the interval was left. The shell at that instant was lighted up to great advantage, so that all the colors appeared perfectly distinct, and in their respective places. These colors continued visible for several minutes, and when they ceased to appear, a white purplish light occupied their places, which lasted for a considerable time. And notwithstanding this experiment was repeated with the same and other shells, the colors continued in their respective relative situation, and nearly of the same degree of brilliancy.—*Adams.*

324. Pass a shock over the surface of native sulphate of barytes, this mineral will appear luminous with a fine green light; the same is the case with the native carbonate of barytes, but less brilliant.—*Singer.*

325. Pass the shock over or through dry acetate of potass or succinic acid, or boracic acid, it will appear green and very brilliant; with borax more faint.—*Singer.*

326. If the shock be taken over rock crystal, it will be first red aud then white; if over quartz, it will be of a dull white.—*Singer.*

327. *To fire ether or spirits of wine.*—Procure a small metallic cup similar to that presented in the following cut:—Fix it by its stem to the prime conductor. Pour a small quantity of spirits of wine into the cup or still better of ether, take a spark through the middle of the spirits, and they will become inflamed. To insure perfect success at all times, a thing absolutely necessary in a lecture, let the cup be heated slightly before being attached to the conductor. This will occasion an evaporation from the spirit, and



the spark the more readilv inflame the spirituous vapor.

If you have not a cup similar to the above, a common table spoon, warmed and held in the hand, will completely answer the purpose. While so held full of spirit, the spirit is to be held towards the ball at the end of the prime conductor, so that a spark may pass through the liquid.

328. Or, let a person standing on an insulated stool and connected with the prime conductor hold the cup with spirits in his hand, and let a person on the floor take a spark through them, and they will be fired. The experiment answers equally well, if the person on the floor holds the cup or spoon, and the insulated person takes the spark.

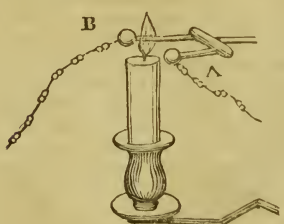
329. The foregoing experiment may be agreeably diversified in the following manner. Let one electrified person, standing on an insulated stool, hold the spirits; let another person, standing also on an insulated stool, hold in his hand an iron poker, one end of which is made red hot; he may then apply the hot end to the spirits, and even immerge it in them, without firing them; but, if he put one foot on the floor, he may set the spirits on fire with either end. The spirits cannot be kindled by an insulated person; because, as the electric fluid cannot escape through him to the earth, he is incapable of drawing a spark sufficiently strong to inflame them.

330. *Hydrogen inflamed.*—Make some hydrogen gas, by putting a handful of iron nails, or the same quantity of pieces of zinc into a wine bottle; to these add half a pint of water and a wine glassful of sulphuric acid. Have ready prepared for the bottle a cork which fits it, and through which the stem of a tobacco-pipe passes. The mixture will soon throw up bubbles of gas; when it is supposed that these have displaced the air of the phial, cork it up, so as to suffer the gas to pass out only through the stem of the pipe. Here it may be collected in a collapsed bladder fastened to the other end of the stem, or, if preferred, the bladder may be tied to the top of the cork itself. The gas will soon fill the bladder. When enough for use has been collected, the stem may be broken, so as to separate the bladder and the bottle, and the part still attached to the bladder is to have a small plug inserted in it, lest the gas should escape. Procure some strong soap suds and blow some bubbles by means of the gas collected. Take care to touch these when ascending with a ball fastened to the end of the flexible tube described in page 63, the tube being connected with the prime conductor when the machine is in action, and held by its glass handle. A spark will thus

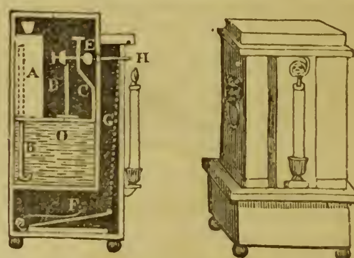
be given to the soap bubble, and the gas inflamed. It will give a loud report at the moment of inflammation.

331. *Lighting a stream of hydrogen.*—While hydrogen gas is passing out of the bottle in which it is generated take a spark through the stream of the gas, by holding the bottle in one hand, so that the top of the pipe is near to the conductor, and taking a spark from it, with a metal ball held in the other, the gas will be inflamed.

332. *Lighting the candles of a theatre, &c.*—The carburetted hydrogen or coal gas of the shops will answer the same purpose. Let an apparatus be constructed similar to the following, which represents two chains A and B, attached to two balls projecting from a wall by means of two glass rods. The apparent candle is a tube, through the top of which gas is issuing in a small stream. If a shock from a Leyden jar be sent along the wires or chains, however long those wires may be, the gas will be inflamed, and the apparent candle lighted. Several contrivances of the same kind may be placed in different parts of a theatre, when, if the chain passes from one to the other, all the candles will be lighted at the same moment. Be it observed, that the interval between the balls A and B should be very small, much less than represented in the cut. Even ¼ of an inch is quite sufficient, and the whole apparatus may be entirely concealed, if wires are used instead of chains; and supposing the candle-shaped case be made of baked wood or ivory, the wires may traverse up one side and down the other, branching off from the lower part, where being in the shade they would not be observed.



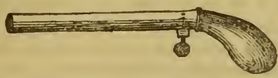
333. *Volta's hydrogen lamp.*—Volta contrived a lamp upon the principle of the electrophorus, which lighted hydrogen by a very small spark. His lamp is shown in the following cut, where the instrument is seen in perspective and in section. A is a leaden bottle, which has a pipe from the top of it, through the bottom, and extending some distance below, as shown at B. The case is divided into two compartments, the lower one into which B dips is filled with water. The bottle A is for the generation of hydrogen gas. The gas passes down the tube B through the water, and occupies the tube and cock E. Whatever surplus gas there is, presses upon the surface of the water, and drives that water up the tube C into the upper vessel. The tube C ought to reach near the bottom of the reservoir O. Whenever the cock E is turned, the gas rushes out of a small orifice H, where there are two wires separated from each other by a small interval. One of these wires is connected to the lower plate of the electrophorus seen at F, and is a fixture. The other wire G is connected with the cock E, and meets the former wire near enough to give a spark, whenever the cock E is turned; and as this also lets on the gas, this is inflamed by the spark, and in its turn lights the candle in the front of the instrument. The only trouble required to put this ingenious machine in action is to rub the lower plate of the electrophorus with a warm flannel occasionally to excite it.



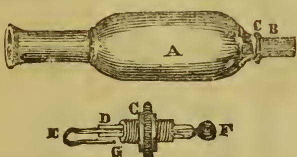
It is evident that by means of a small jet of gas issuing from a minute orifice, as in the above instrument, and a shock or spark passing in like manner over a minute interval in the jet, candles properly placed may be ignited, and in any number, provided the aggregate of all the spaces over which the electric fluid has to skip be not greater than the striking distance of the jar. Also it will be remarked that a shock from a jar is better than a spark for most experiments in which apparatus are attached to walls, &c., as the wires, &c. need not then be insulated, although they necessarily must be so if a spark only is employed.

334. *Hydrogen pistol.*—The simplest form of the hydrogen pistol is seen beneath. It consists merely of a tube of brass, about ½ an inch in diameter, and 5 inches long, fastened on to a baked wooden handle, shaped like that of a common pistol. Where the trigger is ordinarily placed, is a short ivory tube, which fastens into the brass tube, so as to reach about half way across it. This piece of ivory is pierced so that a wire may pass through it. The inner part of the wire is at a small distance from the inner part of

the top of the tube, and the outer end of it is terminated by a small ball. If then a spark be taken by the barrel, and at the same time that the finger touches the ball of the trigger, a spark will pass from the tube to the point of the wire inside, and thence to the trigger to the hand.



A better kind of electrical pistol is seen beneath. A is a chamber, which with its tube is of metal. A cap covers the end B. Upon taking this cap off, and unscrewing the instrument at C, the structure will be seen, as shown below the cut of the perfect instrument. C is the screw, one end of which fits upon A, the other end is for the cap. In the middle of C is a short glass tube D, through which runs a wire E F, terminated by a small ball at F, and bent upon itself at E, in such a manner that the end of it very nearly touches the screw of C, as shown at the point G. The spark being received at F, runs along the wire, leaps the interval G, where it fires the gas, and finally passes to the outer tube which is held in the hand.

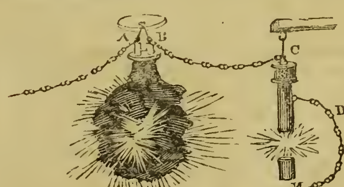


335. *To fill the pistol.*—Apply the mouth of the pistol to the opening of the bottle, and the common and inflammable air will mix together, because the former being heavier than the latter will naturally descend ; keep the pistol in this situation about fifteen seconds, then remove it, and cork the pistol. If the pistol is held too long over the bottle, and is entirely filled with inflammable air, it will not explode; to remedy this, blow strongly into the muzzle of the pistol ; this will force out a quantity of the inflammable air, and occasion a quantity of common air to enter the pistol, which will then readily explode.

336. *To fire inflammable air.*—Bring the ball of the pistol which is charged with inflammable air near the prime conductor, or the knob of a charged jar ; the spark which passes will fire the inflammable air, and drive the cork to a considerable distance. This air, like all others, requires the presence either of common air, or else of vital air, to enable it to burn ; but. if it is mixed with a certain quantity of common air, an explosion will take place in passing the electric spark through it.

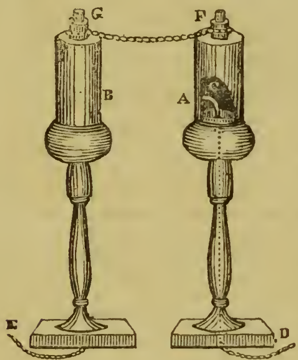
337. *Mr. Cavallo's pistol.*—Mr. Cavallo recommends a pistol made in the following manner, to those who wish to make experiments on the explosion of hydrogen and oxygen, or with known quantities of common air and hydrogen. It consists of a brass tube, about 1 inch in diameter and 6 inches long, to one extremity of which a perforated piece of wood is securely fitted ; a brass wire, about 4 inches long, is covered, except its ends, first with sealing wax, then with silk, and afterwards with sealing wax again. This wire is to be cemented in the perforation of the wooden piece, so as to project about 2 inches within the tube, the rest is on the outside ; that part of the wire which is within is bent, so as to be only about the tenth of an inch from the inside of the brass tube. An instrument such as this forms part of the apparatus to the next experiment, and a shock passing from C to D inflames the gas within.

338. *To inflame a bladder of gas.*—Procure a plug of baked wood or ivory, about the size of a large cork, and insert in it two wires, at about ½ an inch distance from each other, as is shown at A and B. At the lower end the wires are to approach to within ⅛ of an inch of each other, at the upper end they may be turned into loops or rings, that the whole may be hung up to a ceiling or wall, by a silk cord, and the loftier the ceiling, or more distant the wall, the better. In the middle of the ivory let there be a third hole, not stopped by a wire, in order that a bladder may be filled with hydrogen gas by means of it. A plug must be ready to fit it. Tie a bladder tightly to the ivory tube, fill it with hydrogen gas, mixed with common air, plug up the hole where the gas entered, hang up the bladder, connect two chains to it, one to each of the wires, send a shock through the whole, and the gas will be inflamed, making a terrific explosion.



339. *The magic vases.*—This amusing piece of apparatus is seen annexed. The structure is evidently upon the principle of the electrical pistol. The two vases A and B have each a hollow brass chamber at top, part of the side of which is cut away in one of the figures to show the wire withinside. The wire is continued downwards through the entire stem, and connected with the chain at the bottom. To use the vases, load them

in the same way as the pistol was loaded with hydrogen gas, and cork them up; after which, connect the tops F and G together by a chain, as represented; also let the chain E be attached to the discharging rod, and the chain D to the outside of a charged jar. Upon making the discharge, the fluid will pass up the stem of the vase connected with E, pass out at the end of the wire, across to the side of the chamber, setting fire to the gas within and throwing out the cork. It thence proceeds by the chain to the outer case of the other chamber to the point of its wire, inflaming the gas in the other vase, and downwards out at the foot along the chain D.

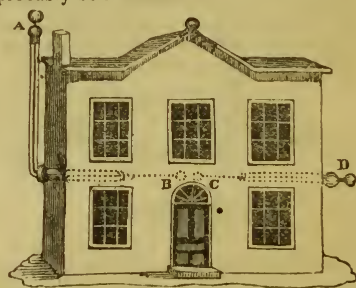


If the chain at top be changed to a wire a mile in length, so that the fluid may pass the whole of that distance, yet the rapidity of its motion is such, that the two chambers of gas will explode so simultaneously as to be heard but as one report. A variety of this experiment, and which occasions considerable amusement, is made by asking a person to hold the vases one in each hand; when the shock is passed he will of course feel it, as it will pass through his arms, and being accompanied with a loud report, it will, though trifling in itself, mostly occasion considerable alarm to the person receiving the shock, and equal amusement to the bye-standers who know that his alarm is groundless.

340. *Rosin inflamed.*—Wrap round one of the balls of a discharging rod some tow, let it lie loosely, and when tied on dip and roll it in powdered rosin, discharge a Leyden jar with this discharger quickly, when the rosin will be inflamed.

341. Fill a flat porcelain dish with water, and on the surface of the water strew a quantity of powdered rosin; place two wires on the opposite sides of the dish, with their ends near the surface of the water, and at 4 or 5 inches distance from each other; pass the charge of a jar from one wire to the other, and the resin in the track of the explosion will be inflamed.

342. *Rosin house or fire house.*—The following cut shows what is commonly called the rosin house, but it is not so likely to succeed as the simple means of firing rosin first given (in *Ex.* 340.) The whole external case is of tin, painted in the front according to the fancy of the maker. Attached to the chimney and side of the house is a glass tube, terminated by the brass ball A, with which is a wire proceeding down the tube into the house, where it is terminated by a second ball B. Through the opposite side of the house is a second glass tube, wire and two balls, marked at C and D. The wire of this part is capable of sliding backwards and forwards, that the balls withinside may be made to approach each other more or less according to the strength of shock to be passed through them. The balls C and D are loosely covered with tow, and dipped in or sprinkled with powdered *yellow* rosin. When the shock is passed from A to D, the rosin will most probably be inflamed.

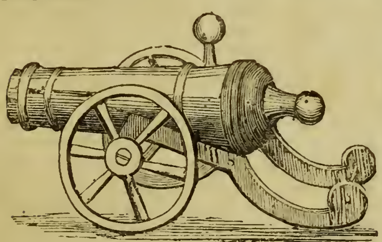


343. *Gunpowder fired or scattered.*—There are several ways of firing gunpowder by means of electricity, but it is only to be done with absolute certainty when the fluid is made to pass through a portion of water, or other conductor which is sufficiently imperfect to allow the fluid to pass slowly along its course, as it appears than when the fluid passes with its accustomed rapidity through metallic conductors, with but a small space of air intervening, it has not time to ignite the powder. The latter is therefore scattered but not inflamed, and even when the powder is tightly compressed into a cartridge or rammed in a cannon, the firing of it is by no means certain even by a very powerful battery, whereas by making a minute quantity of water a means of communication between the different sides of the jar or battery employed, a very small charge, and indeed a very small jar will be sufficient We have often failed in firing gunpowder by a large battery according to the old method, and always succeeded by the method recommended

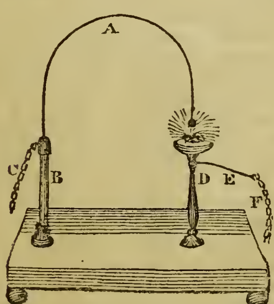
by Mr. Sturgeon about to be described, even with a Leyden jar holding no more than a pint. It may be important to consider these various methods, as the right understanding of them may assist in maturing an application of this science lately introduced, namely, the inflammation of charges of gunpowder, intended for the blasting of rocks.

344. Fix a small cartridge on a metallic point, which is fitted to a wooden or glass handle; make a communication from the wire to the ground, then present the cartridge to the knob of the phial, and the gunpowder will be fired by the passage of the electric stream through the cartridge.—*Adams.*

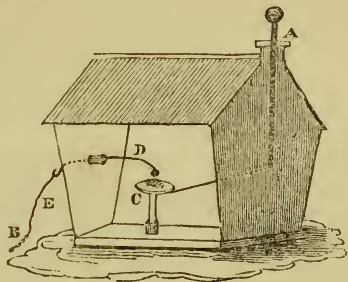
345. *Electrical cannon.*—The following cut shows the electrical cannon. The ball at the top has a wire attached to it which passes down a short tube of ivory into the chamber of the cannon, in the same manner as in the hydrogen pistol. The cannon which has a small bore is charged in the usual manner with gunpowder. The wire of the ball is pushed down to its place, and when the point of the wire is within a short distance of the lower part of the bore it is properly prepared. The outer part of the pistol is connected with the outside of the charged phial, and by making a connexion by means of the discharging rod with the inside or knob of the bottle, the charge will pass, and *sometimes* inflame the gunpowder.



346. *Sturgeon's firing of gunpowder.*—Construct an apparatus as shown in the following cut, where A is a wire with a very small ball at one end, and screwed into a brass cap at the other. B is a glass pillar. C a chain. D a metal stand. E a piece of linen thread dipped in water, connected with D, and with the chain F. To use the instrument, place a little gunpowder upon the top of D. Wet the thread E. Connect C with the outside of a Leyden jar, and F with the inside of the same by the discharging rod. When the shock passes, the gunpowder will be inflamed.

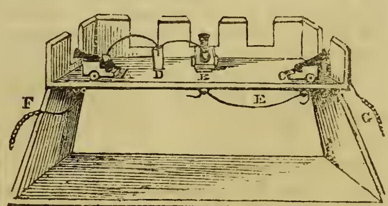


347. *Electrical powder-house.*—The following cut shows the apparatus so called; one side is removed to show its interior.



It is made of seven pieces of wood, so united together by hinges, that when the powder withinside is inflamed the whole of the sides will fall down flat with the table. A represents an ivory cup filled with very dry gunpowder, having a wire through each side, and nearly meeting in the middle; a shock is passed from P through a piece of *wetted thread* B, then through the powder, and out again to the chain N.

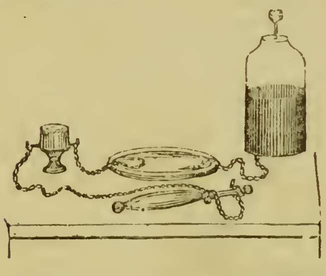
348. *Electrical fort.*—The next cut represents a fort of baked wood with three cannons. They are so connected, that if a shock be passed from G to F, it shall pass through all the cannons, at the same time there shall be such a disruption of contiguity as that the gunpowder with which the cannons are fired shall receive the shock; and if, as we have before observed, a string dipped in water, or a plate of water be made a part of the circuit, it will at the same time be inflamed, and in each case so instantaneously, that the various cannons, however many of them there may be, will go off, with but a single report. The chain G proceeds to C,



where it enters the cannon by a wire passing through a small piece of ivory. The outside of this cannon is connected with the wire E. This passes to the outside of the next cannon B. A nozzle of ivory in the touch-hole of B conveys the circuit to the touch-hole of the cannon A, the outside of which leads to the chain F. The wire between A and B is supposed in the cut to be supported by a short glass rod, or a stick of sealing wax, between the two cannons. The wetted string may be attached to either end as may be most convenient.

349. *Gunpowder scattered.* — Use the same apparatus, and pass the shock through it in the same manner as in the last experiment, but take the thread away and substitute a wire or chain in lieu of it. Upon the shock passing, the gunpowder will be scattered, but not inflamed.

350. *Gunpowder inflamed by a shock through water.*—The *Ex.* 346 may be varied by adopting the following apparatus, and which is so plain as scarcely to need an explanation. The gunpowder is placed in an ivory cup, with two wires at a short distance from each other in the centre chamber, one chain leads to a director or discharging rod ready to discharge the bottle, the other dips into an earthenware dinner plate, full of water. The gunpowder will be fired when the shock passes.



The following experiments are not instances of combustion, but are so closely connected with the part of the subject we are now considering, that they may be introduced, if not with propriety, at least with convenience.

351. *The chain illuminated.*—Form an iron chain by cutting wire into lengths about 2 inches each, and turning up the ends, link one piece to another; hang this around a room by silk strings, and pass a shock along it, when it will appear beautifully luminous at every link of the chain; appearing like a continued line of the most brilliant star-like sparks.

352. *The luminous discharger.*—Bend a tube of glass into a semicircle, put a brass cap on each end, and let the caps be connected by an iron chain which passes through the tube. Furnish it with a wooden handle. Discharge any Leyden jar with this discharging rod, and the chain will be beautifully luminous.

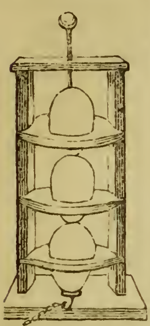
353. *Spiral illuminated.*—Take a round board well varnished, and lay on it a chain in a spiral form, let the interior end of the chain pass through the board, and connect it with the coating of a large jar; fix the exterior end to a discharging rod, and then discharge the jar; a beautiful spark will be seen at every link of the chain. The chain may be sewed on in order to retain it in its position.

354. *Marks impressed on paper.*—If instead of using a board for the above experiment, we lay the chain either in a spiral, or any other manner on a sheet of dry white paper, supported by a book, when the shock is passed, the chain will be illuminated as before, and will leave a black burnt mark upon the paper at every link of the chain.

355. *Luminous board.*—Procure a board of any length, and send it to a baker's, to be baked for two hours; afterwards plane it, and lay along it, seven, nine, eleven, or thirteen strips of tin-foil, an eighth of an inch wide. These slips are to be put on and connected together at the ends, exactly in the same way as the strips upon the glass in *Ex.* 245, except that they are to be put on with glue. The spaces between the slips being carefully cleaned off immediately with warm water and afterwards wiped dry. Draw with chalk any desired word or sentence upon the slips, and with a penknife cut through the tin-foil slips wherever a spark is desired to be. Be the cut ever so minute, provided it pass quite through the slip, it will suffice. Before use, let the board at all times be well dried by standing at the fire for some hours, as the glue will be very apt to attract moisture from the air. Pass a shock from one end of the board to the other, and the whole will become luminous from end to end. We have by this means sent the shock of a gallon Leyden jar through an extent of 180 feet, illuminating four boards, with the words "Good night, all's well," in well proportioned letters, 13 inches high, and by the same shock also

rendered luminous 300 feet of iron chain, and fired a bladder of gas in the distance.

356. *Eggs illuminated.*—This is usually done by means of a little apparatus called the egg stand, and which is represented in the margin. This consists of a wooden frame, with a piece of metal let into the bottom; a chain attached to this is connected with the outside of a Leyden jar. There are three wooden slides to hold as many eggs. A wire and ball passes through the upper part of the frame, so as to touch the top egg, and the eggs are to touch each other. A shock is passed through the eggs by touching the upper ball with a discharging rod, which reaches to the inside of the charged jar, whose outside is united to the chain at bottom. The eggs will become beautifully luminous, and the shock in passing will make a sound as if the egg shells were broken, as indeed they will be if the shock be large. A quart jar is quite sufficient for this experiment. The eggs, if eaten immediately, will have a strong taste of phosphorus; and will very soon afterwards become putrid, that is to say, in two or three days. When broken, the white and yolk will be found completely intermingled with each other, if several shocks have been passed through the eggs.



357. *Illumination of oranges.*—Substitute three oranges for the eggs of the last experiment, and send the shock through them; they will appear luminous. As oranges are not good conductors, the experiment succeeds best when the upper wire is made to penetrate the topmost orange, and when there is a short piece of wire between every two, it being thrust about half an inch through the rind of each. A single orange may very conveniently be illuminated by thrusting through its sides the points of the wires of the universal discharger.

The most remarkable effects of combustion that are produced by electricity result from its action on metals and their oxydes.

358. *Gold leaf melted.*—Place a strip or silver or gold leaf about ½ an inch wide on white paper, pass a strong shock through it, the metal will disappear with a bright flash, and the paper will be stained with a purple or grey color.

359. Take three pieces of window glass, each an inch wide, and 3 inches long, place them together with two narrow slips of gold leaf between them, so that the middle piece of glass has a strip of gold on each of its sides; the extremities of the gold slips should project a little beyond the ends of the glass; pass the charge of a large jar through the gold strips, they will be melted and driven into the surface of the glass. The outer strips of glass are usually broken, but that in the middle frequently remains entire, and is marked with an indelible metallic stain on each of its sides where the gold leaf rested. The press of the universal discharger, described in page 65, is very convenient for holding the slips when performing this experiment.

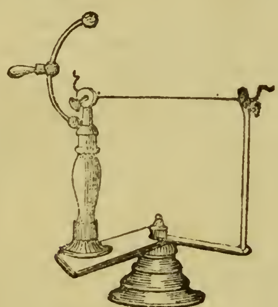
The colors produced by the explosion of metals have been applied to impress letters or ornaments on silk and paper. The outline of the required figure is first traced on thick drawing paper, and afterwards cut out in the manner of stencil plates. The drawing paper is then heated and placed on the silk or paper intended to be marked; a leaf of gold is then laid upon it, and a card over that; the whole is then placed in a press or under a weight, and a charge from a battery sent through the gold leaf. The stain is confined by the interposition of the drawing paper to the limit of the design, and in this way a profile, a flower, or any other outline figure may be very neatly impressed.

360. *Wire melted.*—Pass a strong shock through an inch or two of fine watch pendulum wire, and it will be melted. Try this experiment until you have found the greatest length of wire that can be melted by a certain jar, charged to a certain height by the quadrant electrometer. Then join a second jar to the first, charge them to the same height as before, and increase the length of wire to four times that which was melted by the single jar, and the whole of this will in like manner run into drops. If there are three jars, it will melt 9 inches of wire, and so on for other numbers.

361. Instead of charging the single jar to the same intensity as before, use two jars, connect them together, and charge them to half the intensity; there will be melted the same length of wire as by the single jar which was charged to double the height.

The fusion of wire may therefore be employed as a measure of the quantity of electricity accumulated on any charged surface; for the preceding experiments show that any given quantity of electricity will fuse the same length of wire, whether it be disposed in two jars or one; and hence it may be concluded, that the greater or less intensity of a charge does not materially affect its wire-melting power. This test is therefore practically useful, for the various electrometers measure only the intensity, and are

equally affected by one jar as by a battery of one hundred. When the fusion of wire is taken as a test of electrical power, care should be taken that the length of the circuit is always the same, and that the degrees of ignition are uniform; for a wire may be melted with but slight variations of appearance, when very different quantities of electricity have been transmitted through it. The lowest degree of perfect ignition ought therefore to be obtained in all comparative experiments, and its phenomena should be uniform, that is, as soon as the discharge is made, the wire should become red hot in its whole length, and then fall into drops. In order to ensure a perfect uniformity in this respect throughout a series of experiments, Professor Hare has invented the apparatus shown beneath:—This consists of two bent arms, which diverge from a centre, as a pair of compasses, and when adjusted are held tight by a screw at the centre. A reel of fine pendulum wire is fixed at one end by a screw, and at the other by a small pair of nippers. The whole is of baked wood, with glass supports.



The melting of metals by electricity may be considered as a chemical rather than a mechanical effect, particularly as upon examination the melted metals are found afterwards not in a metallic state, so much as in that of an oxyde. It is not supposed in these cases that the electric fluid acts otherwise than by raising the temperature of the metal, so as to enable it to combine with the oxygen of the surrounding air; the same cause will often reduce an oxyde to a metallic state, particularly of such metals as are thus reduced by heat. Mr. Cuthbertson made many experiments upon this subject, using for the performance of them a somewhat extensive battery, though such is not by any means necessary for the majority of cases. Besides the reduction of metallic oxydes, electricity often occasions still more evident chemical changes, and although its power in this respect does by no means equal that of galvanism, yet when we are enabled to procure a powerful stream of the fluid, as in the electricity of steam afterwards discussed. the effect of free electricity in producing chemical and magnetic changes is by no means inconsiderable. The following experiments will illustrate a few facts relative to this subject.

362. *Prismatic colors produced.*—Place a smooth and flat piece of metal between the points of the universal discharger, pass several explosions of a battery through the wires, and the discharger will gradually form on the metal different circles, beautifully tinged with the prismatic colors. The circles appear sooner, and are closer to each other, the nearer the point is to the surface of the metal. The number of rings or circles depend on the sharpness of the points, the experiment therefore succeeds better if a sharp needle is fastened to one of the points of the discharger. This experiment has been thought to account for the *fairy rings*, discoverable on downs and meadows, but this appearance is now thought to be derived from the growth of a certain species of fungus, which has the peculiar property of not growing on any spot where it has grown before; a single plant then first arises, the second season others spring up around its site, the third year still further off, and so on for a length of time. We do not give the above as our own opinion, but as one pretty general among naturalists. These prismatic electrical circles are marked most distinctly upon such metals as melt with the least heat.

363. *Reduction of vermillion.*—Color a card with vermillion, mixing it up with water and a little gum, such as that already prepared in the boxes of water colors, place it when dry upon the table of the universal discharger; the wires being one on each side of the card, at about the distance of 1 inch from each other. If the charge be now passed through the wires, the fluid will pass across the surface of the card to the part over the negative wire, and it will there perforate the card in its passage to the negative wire. The course of the fluid is permanently indicated by a neat black line on the card, reaching from the point of the positive wire to the hole, and by a diffused black mark on the opposite side of the card around the perforation, and next the negative wire. These effects are very constant, the black line always appearing on the side of the card which is in contact with the positive wire, and the perforation being near the negative wire.

364. Draw a line ½ an inch broad on a card with tincture of litmus, take a number of sparks from a machine along the wetted line, and the litmus will be changed to a red color; this arises from the action of the electric fluid occasioning the formation of nitric

acid by a chemical union of the nitrogen and oxygen of the air through which the fluid passes.

365. *Decomposition of iodide of potassium.*—Damp a piece of white paper with the iodide of potassium; upon taking a series of sparks along the card the compound is decomposed, the oxygen of the air combines with the potassium, and suffers the iodine to escape, as may be known by the peculiar odour of that substance, and by holding over the card any article which has just been starched, and which by the action of the iodine will become of a bright blue color.

366. *Reduction of tin.*—Introduce some oxyde of tin into a glass tube, so that when the tube is laid horizontally, the oxyde may cover about ½ an inch of its lower internal surface. Place the tube on the table of the universal discharger, and introduce the pointed wires into its opposite ends, that the portion of oxyde may lay between them. Pass several strong shocks in succession through the tube, replacing the oxyde in its situation, should it be dispersed. If the charges are sufficiently powerful, a part of the tube will soon be stained with metallic tin, which has been revived by the action of the transmitted electricity.

367. *Reduction of mercury.*—Perform the same experiment with vermillion in a tube, the mercury will be separated, and that with such facility that the charge of a very moderately-sized jar will be fully sufficient.

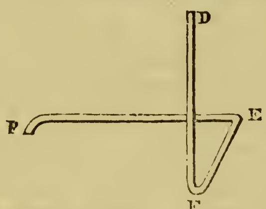
368. *Acid and alkaline effects.*—Take a small glass tube of the shape of the letter V, each arm of it being about 4 inches. Fill it to 2 inches in depth with water slightly colored with litmus. Put a cork in each end, with a very fine pointed wire projecting inside the corks, so as just to touch the liquid; connect the outer end of one wire with the prime conductor, and the end of the other wire with the cushion; the chain from the latter, and which usually connects it with the ground being removed. Upon passing a stream of electricity through the tinged water, the positive end will soon appear red, owing to the formation of nitric acid. If, when this is the case, the apparatus is reversed so that the positive side becomes the negative, the blue color will be restored, showing that in free electricity, as well as in galvanism, the two poles produce acid and alkaline properties. In this experiment it is best to have the wires covered with sealing wax, except at their points.

369. *Oil of tartar crystallized.*—Take a glass tube about 4 inches long, a quarter of an inch in diameter, and open at the both ends; moisten the inside of the tube with oil of tartar per deliquiem, that is, pearlash which has liquified by contact with the air. Then fix two pieces of cork into the ends of the tube, and pass a wire through each cork, so that the ends of the wires which are within the tube may be about three quarters of an inch asunder. Connect one wire with the outside coating of a large jar, and form a a communication from the other to the ball of the jar, so as to pass the discharge through the tube; repeat this several times, and the oil of tartar will very often give manifest signs of crystallization. This is supposed to arise from the formation of nitric acid by the electrical action upon the air, and this uniting with the oil of tartar forms nitrate of potass or saltpetre, the same as in *Ex.* 364.

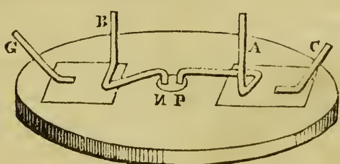
370. *Decomposition of water.*—The power of electricity in decomposing water was first discovered in 1789 by Mr. Cuthbertson. The manner of performing the experiment was by using a glass tube, a foot long, and ⅛ of an inch in diameter, through one end of which was inserted a gold wire, which projected an inch and ½ into the tube, which, after its insertion, was hermetically sealed. The other end of the tube was left open, except that a cork loosely covered it; a wire of the same description passed through this cork, so that its extremity came to a distance of about ½ an inch from the first wire. The tube was then filled with distilled water, from which the air had been extracted by the air pump, and inverted in a vessel containing mercury. A little common air was let into the top of the tube, in order to prevent its being broken by the discharge. Electrical shocks were then passed between the two ends of the wires through the water in the tube, by means of a Leyden jar which had a square foot of coated surface. At each explosion, bubbles of gas rose to the top of the tube, and when sufficient water had been displaced to lay bare the wires, the next shock kindled the gases, and caused their reunion; thus decomposition and recomposition were effected by the same agent.

Dr. Wollaston published in the *Philosophical Transactions* a description of analysing water by the transmission of *sparks*, instead of shocks. The following is from his paper on the subject:—"Having procured a small wire of fine gold, and given to it as fine a point as I could, I inserted it into a capillary glass tube, and after heating the tube so as to make it adhere to the point, and cover it at every part, I gradually ground it down, till with a pocket lens I could discern that the point of gold was exposed. The success of this method exceeded my expectations; I coated several wires in the same manner, and found that when sparks from the conductors before mentioned were made to pass

through water, by means of a point so guarded, a spark passing to the distance of $\frac{1}{8}$ of an inch would decompose water, when the point exposed did not exceed one seven-hundredth of an inch in diameter. With another point which I estimated at one fifteen thousandths, a succession of sparks one-twentieth of an inch in length afforded a current of small bubbles of air." In these experiments the gases were liberated at both poles. Dr. Faraday however has devised a simple plan for evolving the gases, so that oxygen shall make its appearance at the one pole and hydrogen at the other, and also for other electro-chemical decomposition. The following is Mr. Faraday's description of his apparatus. "Upon a glass plate, placed over, but raised above a piece of white paper, so that shadows may not interfere, put two small slips of tin-foil; connect one of these by an insulated wire with a machine, and the other with the discharging train or negative conductor. Provide two pieces of fine platinum wire, bent as in the figure annexed, so that the part D F shall be nearly



upright, while the whole is resting on the three bearing points P E F, place them as shown beneath, the points P N become then the decomposing poles."



371. Place a large drop of muriatic acid, rendered blue by sulphate of indigo, so that P and N may be immersed in it at opposite sides; then send a current of electricity through it from a good machine, and chlorine (shown by its bleaching effects) will be evolved at P.

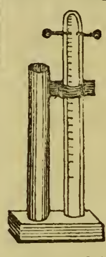
372. Place a drop of solution of the iodide of potassium, mixed with starch, between the poles, and the current will evolve iodine at P.

373. Put a drop of solution of copper between the poles, and the current will then cause the precipitation of metallic copper at N

374. Moisten a very small slip of litmus paper in a solution of caustic potash, and then pass a succession of sparks over its length in the air, the electricity will by degrees neutralize the acid, and consequently form with it the nitrate of potass or saltpetre, so that the paper becomes touch paper.

375. *The composition of water.*—In the experiments on the electric pistol the noise and flash of light were occasioned by the chemical union of the hydrogen, or gas injected into it with the oxygen of the air. Now chemists are aware that this union produces water, this is evident, by inspecting the pistol after it has been several times fired, when it will be found quite damp with the moisture so formed.

376. *Eudiometers.*—The fact of certain gases being inflamed by the electric spark

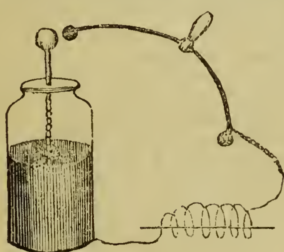


has given rise to various instruments called eudiometers, one of the most simple of which is shown in the margin. It consists of a thick glass tube closed at the upper end, and open below, where it dips into a cup or basin of mercury. It is graduated along the side, and has two wires through the upper part which approach each other. The tube may be supported in any convenient manner. The tube is filled with mercury or water, (according to the kind of gas to be operated upon); it is then reversed, and the gas to be operated upon suffered to ascend the tube, until a certain quantity has been introduced. The electric spark or shock is then passed from the one wire to the other, when the gas is inflamed. The result is seen by the product left. In some cases the maximum effect takes place with the first shock; with others not until after some hours' electrization. The following table shows the result of all these actions:—

Operated upon.	*Result.*
Common air and hydrogen....	Water and nitrogen.
Oxygen and hydrogen	Water.
Chlorine and hydrogen	Hydrochloric acid.
Hydrochloric acid and oxygen	Chlorine.
Carbonic oxide and oxygen....	Carbonic acid.
Nitrogen and oxygen	Nitric acid.
Sulphurous acid and oxygen ..	Sulphuric acid.
Oxygen and ammonia....	Water and nitrogen.
Hydrochloric acid	Hydrogen.
Fluoric acid	Hydrogen.
Nitrous gas..............	Nitric acid and nitrogen.
Sulphuretted hydrogen	Sulphur & hydrogen.
Ammonia	Hydrogen & nitrogen
Olefiant gas	Charcoal & hydrogen

The communication of magnetism to needles depends upon a fact which was

unknown when experiments with that object were first made; that is, that the electrical fluid and the magnetic fluid act in directions opposite to each other. Thus magnetism induces a magnetized needle to turn north and south, or in other words, the magnetic fluids of the earth have a tendency or direction to those points, while the electrical currents of the earth have a direction east and west, or round the equator, correspondent to the apparent motion of the sun in its course. It is more than probable that the magnetic currents of the earth are derived from, or occasioned by the electrical; at any rate the science of electro-magnetism shows us that whenever an electrical current sets in one direction, any matter which has a tendency to become magnetic will arrange itself at right angles to the electrical course. In magnetizing a steel needle by electricity, therefore to produce a constant effect, it is necessary to lay the wire which conveys the fluid *across* the needle to be magnetized. If the electrical current crossing it once only produces a certain effect, crossing it twice will produce one that is double; a third course will be still stronger, always allowing



the fluid to run in the same direction. Now the only way to make an electric shock pass several times across a needle without passing through it, is to twist the wire which conveys the current into a helix around the needle, the latter being for the time wrapped in paper, and the various coils of the helix being drawn out, so that they shall not touch each other, as represented in the preceding cut. That end of the needle nearest to the inner coating, or that end which is shown in the cut to be connected with the discharging rod, will be a north pole.

This method of making a magnet by electricity is certain, even with a Leyden jar of a pint size; whereas, by the old methods described beneath, the success is at all times very uncertain, even with a strong battery. The following are the experiments alluded to.

377. Place a steel wire in the direction from north to south, and pass a moderately strong charge of a battery through it; it will become magnetic, the end that lies southward being the south pole.

378. Render a steel wire slightly magnetic, and place it in the magnetic meridian, with its south pole towards the north. A strong charge of a battery will either destroy its magnetism, or reverse its magnetic poles; if its magnetism is merely destroyed, a second charge will magnetize it anew, but with reversed poles.

379. Place a steel wire in a perpendicular position, and pass a strong charge through it; it will become magnetic, the upper end being the south pole. If this end be now placed downwards, the transmission of another charge will destroy its magnetism, or reverse the poles.

CHAP. X.

THE ELECTROPHORUS AND ELECTRICAL CONFIGURATIONS.

The electrophorus is fully described in page 26. It was once called the perpetual electrical machine, in consequence of its power of giving off electrical appearances for a long time after having been once excited, as already explained. In working this simple and useful instrument, there is a little inconvenience arising from the necessity of touching the upper plate whenever it is placed upon the lower one; this may be obviated by pasting a very narrow slip of tin-foil across the lower resinous plate. As the only object of touching it is to supply it with fluid from the bottom of the lower plate, it is evident that a slip of tin-foil immediately connected with the lower side will still better answer the

purpose than the finger of the operator, which is only connected with the lower side by means of his body, the ground, and the table. Why the electric virtue remains in the electrophorus is easily explained. We will suppose the lower cake to be of resinous substances. When rubbed then with flannel, it becomes negatively electrified; when the upper plate is placed upon it, it will of course by the law of induction induce a contrary state in the upper plate, and the upper plate will necessarily be electrified plus; when a finger touches it, or when it becomes by any other means uninsulated, it will consequently take a spark from the finger or other connecting body. The finger being removed, and the plate lifted up, it will remain electrified plus, and consequently be ready to give up the spark which it had just before taken. Placing it down on the resinous electric a second time, induction is again occasioned, it will again take a spark, which it will in like manner give up. Thus the action is continued for a great length of time, the electricity of the resinous plate being all the time undisturbed, and consequently not dissipated. The following experiments are interesting, and differ from all previously recorded.

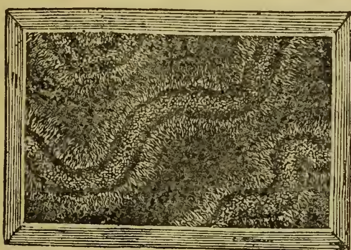
380. *To recover the force of an electrophorus.*— Place the metallic plate on the resinous plate, touch it as usual; then take it up, and discharge it on the knob of a Leyden jar; repeat this operation several times, this will charge the jar. Now place the jar on the cake, and move it over its surface, holding the jar by the knob; this will augment the force of the electrophorus, and by reiterating the operation it will become very powerful.

381. Place a piece of metal on an excited electrophorus, it may be of any shape; a pair of triangular compasses are very convenient for this purpose. Electrify the piece of metal with the power which is contrary to that of the electrophorus, and then remove it by means of some electric, and afterwards sift upon the electrophorus some finely powdered rosin, which will form on its surface curious radiated figures. When the plate is negative, and the piece of metal positive, the powder forms itself principally about those parts where the metal was placed; but if the plate be positive, and the spark negative, the part where the metal touched will be free from powder, and the other parts more covered.

382. *Electrical configurations.* — Draw over the surface of a piece of warm glass, or of a resinous electrophorus, the knob of a charged Leyden jar. This will of course charge or electrify it in those places touched by the knob. Wrap up some powdered rosin in a piece of muslin, and sift it on the excited plate. The rosin will cling in a most beautiful radiated manner to those parts which have been touched by the knob; a small distance beyond this will be a mark quite free from the powder, while over the rest of the plate, and where no excitation has taken place, it will merely cover the surface, as it would any other body not excited. The reason of this action is as follows:—The Leyden jar being charged positively, the streak which it makes upon the plate is of course positive also. Rosin, when let fall from the muslin, is negatively electrified, it therefore clings to the parts charged positively. Then again, we have shown that any body being electrified is surrounded by an electrical atmosphere, and beyond this it produces a contrary state of electricity in any thing adjacent; thus the rosin adheres to the line made by the charged jar, in a dense mass, beyond this it adheres in streams or ramifications, because of the positive electric atmosphere on the two sides. A little beyond this is a negative atmosphere arising from induction, here no powder adheres, but rather is driven away, the particles being negative and repelling each other. Out of the limit of this clear space no action is perceptible, and all appearances purely electrical cease. The next experiment shows this in a still stronger light.

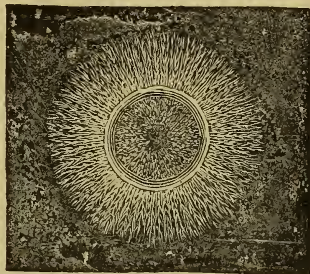
383. *Configuration by red lead and sulphur.*—Mix together equal parts of powdered red lead and sulphur, put them in a small sieve or a piece of muslin. Sift these powders on a piece of warm glass which has been drawn over or touched with the knob of a charged Leyden jar. The powders however intimately mixed will separate from each other, because by the sifting one of them becomes negatively electrified, the other positively. In falling, therefore, each will be attracted by such part of the glass as is in a contrary state to itself, and form distinct lines and marks on the glass of the most extraordinary and beautiful appearance. The red lead being electrified positively by the sifting, adheres to the outside lines in little stars or dots, which as the electricity of the

sulphur is strongly negative, it adheres to the central space, where it appears as a line of small specks or stars, the property of a negative action ; while the red lead is in brushes or ramifications, showing its positive condition. These beautiful figures may be preserved for years if made on a sheet of glass which has a frame to it like a picture, the glass being after the experiment reversed towards the back, so that it may not be rubbed off by accident. A piece of black paper behind it heightens the effect greatly when to be preserved. If too much powder be sifted on it, the surplus may be blown off without injury. The next cut will give some idea, although a very inadequate one, of this beautiful and curious experiment.



384. *Projection of chalk.*—Suspend the lower plate of the electrophorus against the wall, that in this and the following experiments the grosser part of the powder may fall to the ground, and no more adhere to the plate than is attracted there by the electricity diffused thereon. Let a small jar be charged very weakly, draw its knob over the resinous plate, and then taking a clothes brush in one hand, and a piece of chalk in the other, rub the chalk upon the brush near to the surface of the plate ; this produces a plain white line without any ramifications. When the charge is stronger, the ramifications are proportionably extended, resembling so many beautiful white feathers.

385. Place a circular brass plate with an insulating handle upon the resinous plate, and communicate a spark from the charged jar to the brass plate. Take this off by its insulating handle, and project chalk upon the lower plate. This produces a very regular circle of ramifications about 4 inches long, proceeding from the circumference of the space covered by the brass plate, and within the circle are a number of irregular figures somewhat like stars. A shock made to pass through the same plate generally produces more distinct ramifications, and sometimes without any stars within the circle ; at other times with a quantity of minute specks.



386. In performing an experiment similar to the last, let the brass plate be drawn along towards the edge of the electrophorus whilst touched with the knob of a jar ; a very beautiful figure will be produced at the projection of the powder.

387. Draw over the plate a jar strongly and negatively charged, and afterwards a pointed wire, held in the hand only, is to be drawn over the same figure. When chalk is projected, a beautiful ramified figure is produced in the middle of the negative one.

388. A conical tin funnel is to be placed with its base on the middle of the resinous plate, and a negative strong charge given by connecting the discharging rod with the under side of the plate ; then a positive charge is to be given in the same manner. Let the funnel be thrown off, and the chalk projected. Beautiful ramifications are now produced both within and without the circle.

389. A knob of wood, about an inch in diameter, is to be placed upon the wire of a jar which is charged highly positive, and the knob drawn over the plate so as to touch the surface. This produces a beautiful figure, the middle of which is smoothly covered with chalk, and the sides finely ramified with shades.

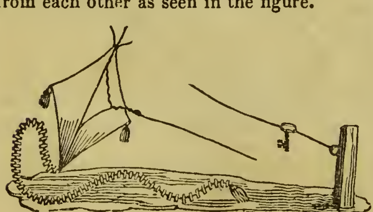
390. Let the flame of a small wax taper be at about an inch distance from the middle of the resinous plate ; then let the knob of a positively-charged jar be suddenly brought to the flame, and both the jar and flame be instantly taken away again. In this experiment when the chalk is projected, a circular space, about 4 inches in diameter, will be clean and free from powder ; the rest of the plate uncovered, except by a great number of small circular or elliptical spots, which shows that the electrical fluid passed to the plate in detached balls, like some atmospheric meteors.

CHAP. XI.

ATMOSPHERIC ELECTRICITY, &c.

MANY atmospheric phenomena have a resemblance to what we may suppose to be occasioned by a great accumulation of the electric fluid. It is therefore not surprising that the earlier electricians acknowledged the similarity of many of those natural phenomena with the experiments which their comparatively small machines enabled them to perform. The very appearance of lightning induced philosophers long to believe that it was only a grander species of electricity, excited without the intervention of human art; but the proof that they should be actually the same fluid, and should arise from the same cause, and be subject to the same laws, was reserved for the comprehensive and active mind of Dr. Franklin. He made the bold assertion, and with a kite made of a silk handkerchief, brought lightning from the clouds, and proved his assertion by performing with it all the experiments then known.

Ex. 391. *Electric kite.*—A kite properly adapted for the purpose of atmospheric electricity may be made and managed as follows:—Tie together in the form of a cross two canes, or still better two thin rods of deal, about 3 feet long each. To the four corners of the cross-sticks fasten the corners of a large silk handkerchief; a loop must be made by piercing a hole in two parts of the handkerchief, and a string fastened to one of the sticks, in the manner of the loop of a boy's kite; indeed a common kite will answer the purpose quite as well as one of silk, except that if it is to be used in stormy weather, the latter will by wet soon become spoiled. The size also is of very little consequence, except that the larger the kite the higher it will usually ascend, and therefore for this cause, and this alone, a large kite is most effective. The kite itself being formed, and having a common kite tail attached to it, or else long strips of calico sewed together, which will be found more convenient; it must be furnished with two or three pointed thin copper wires fastened to the loop, extending upwards a few inches above that part of the kite which flies highest, and projecting from each other as seen in the figure.



The string is the next object of importance, that evidently is the best which has a fine wire or two passing down it. Most persons desiring this string have taken the trouble to wind the wire around the whole length of string previously bought, not knowing that were they to take the fine wire to any string spinner, he would weave it up along with the hemp at once, putting a wire into each strand, if required, and at the expense of a mere trifle additional. Supposing a person should be in such circumstances or situation that this string cannot very easily be procured, the best substitute for the wire will be found in soaking a common string in salt and water for an hour or two previously to using it. It will thus imbibe sufficient moisture to render it a good conductor, even in a very dry atmosphere, where string wetted with water only would become useless. The upper part of the string must be carefully connected with the pointed wire carried above the loop.

The lightning, or electric fluid, being thus attracted at the kite, and led downwards by the string, it must be retained from passing silently to the earth beneath. For this purpose it will be necessary that the lower end of the string be attached to a cord of silk, about 3 feet long, to be kept quite dry, and for convenience of operating, a large key is usually tied at that part where the string and silk are united. The kite being raised, the electric fluid will pass down to the key, here being stopped by the silk cord, it will be given off in sparks or flashes, more or less powerful, in accordance with the quantity of lightning which may be in the air. The operator may easily conduct it elsewhere, or

charge his conductors or batteries without difficulty.

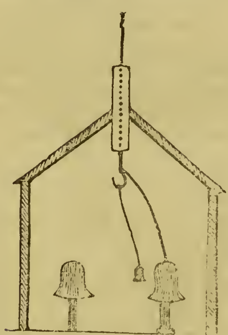
No philosophical instrument is more simple in form and easy to construct than the electric kite, yet no one needs more care in its management. To fly it when a thunder storm is approaching would be attended with the greatest danger, unless every precaution be taken. In this state of the atmosphere the raising and lowering of the kite requires the utmost circumspection ; to let the string wind out immediately from a ball in the hand, making thereby the body a part of the conductor is too venturesome ; the string should pass over and touch an iron railing, or through a ring fastened to a metal rod driven deeply into the ground, whilst the person who holds it is placed upon a dry glass-legged stool, or otherwise insulated ; as for example, upon a pile of books, or paper. When up a sufficient height, the remainder of the string may be fastened to the key, and the operator is then able to remove himself to a safe distance. It is advisable also that the electric fluid should never be introduced into a dwelling house, for a thunder storm is a terrific agent to tamper with, and once invited into our houses, may occasion dreadful damage, ere it be allayed. We have seen flashes o. 4 or 5 feet in length, and once when we left our kite up during a stormy night, the key appended to it seemed as it were a ball o. fire, illuminating all around, and the very kite and string appeared as if enveloped in lambent flames. Fortunately, to operate in weather like this is not necessary. The calmest and brightest evenings of summer; the densest fogs of autumn ; and the clearest frosts of winter, yield mostly as much fluid as is convenient to use ; in either time small sparks will be visible, and may be felt by a knuckle presented to them, when they will be found very different from those usually afforded by the electrical machine. The air will be found positively electrified ninety-nine times out of each hundred, yet the sparks as given by the kite string will be red, comparatively short, make but little noise, and be felt so much more pungent when passing to the hand, that they rather resemble the vibration, or small shock, than that known as the electric spark.

392, The proof afforded by numerous experiments with the electric kite, that the air was at all times charged with electricity, and also that the degree of disturbance and character of the fluid varied at different times, rendered philosophers anxious to construct some simple apparatus which should enable them to do this without the trouble, delay and danger of the kite. They therefore turned their attention to construct more simple instruments, some of which were to be used as a permanent apparatus, others for temporary purposes only. As these instruments varied from each other only in a small degree, and were all dependant upon the same principle, we shall describe but two of them. The first is called from its inventor and use, *Cavallo's atmospheric electrometer.* It is represented beneath, and consists merely of a common jointed fishing rod, without the last or smallest joint. From the extremity of this rod projects a slender glass tube covered with sealing wax, and having a cork at its end, from which a pith ball electrometer is suspended. There is a small string also which runs the whole length of the apparatus, to render the electrometer insulated when required to be so. It is fastened by a pin to the cork ball at the top, so that by pulling the string, it is separated from the cork, and leaves the pith balls suspended from the waxed glass rod ; when used, the rod is thrust out of a window, the string is then pulled ; when the pith balls diverge, they are then pulled in and examined.

393. *Cavallo's rain electrometer.*—This instrument differs from the former in many respects ; it is represented beneath. A is a strong glass tube, about 2 feet and a ½ long, having a tin funnel cemented to its extremity, which funnel defends part of the tube from the rain. The outside surface of the tube is wholly covered with sealing wax. C is a piece of cane, round which brass wires are twisted in different directions, so as to catch the rain easily, and at the same time to make no resistance to the wind. The cane is fixed into the tube, and a piece of wire proceeding

from it goes through the tube, and is terminated by a ring, upon which a pair of pith balls are suspended. This instrument is attached to the side of a window frame, with the funnel projecting outwards, while the pith balls are preserved dry within.

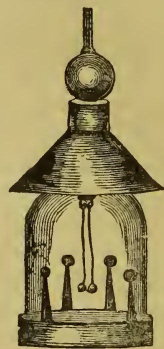
Franklin also contrived one or two electric instruments of the like nature to Cavallo's atmospheric electrometer, the object of which was principally to indicate to him when a thunder storm was approaching. The whole of this apparatus is very simple, consisting merely of a long pointed rod, which proceeded through a glass tube, that was let into the roof of the house. The rod bore at the lower end a clapper, suspended on silk, while there was a lateral communication by means of a wire with an insulated bell. When therefore the fluid was in any considerable abundance, the bell became charged, it therefore attracted the clapper, which being then repelled, discharged itself by striking against the other bell. Thus ringing was kept up.



M. Richman examining an apparatus of this kind too nearly, was struck by the lightning which descended, and fell a sacrifice to his too ardent and incautious love of science.

This last apparatus it is evident will only act when the fluid is in some abundance, and is not adapted to measure or indicate those minor indications which belong to calm weather, while Mr. Cavallo's instruments were more troublesome than they need have been. To obviate these inconveniences, M. Saussure contrived the following more simple and effective instrument :—

Saussure's atmospheric electrometer consists of a glass case or bottle, with a metal foot, and four pieces of tin-foil up the sides in connexion with the bottom. Withinside the glass are two very fine silver wires, swinging freely in a loop above, and ending below in two small pith balls. The upper part of the instrument is a brass cap, to defend the bottle from the wet, terminated by a ball and a rod of 3 or 4 feet in length, made in joints, and pointed. (The upper wire is left out in the cut) In fine weather the hood or cover is taken off. When standing out of doors, the pith balls diverge, as soon as fluid is attracted by the point of the rod



The above remarks and experiments show not merely that electricity exists in the atmosphere, but that it is sometimes at least in an accumulated form, or similar to that in which we witness it in the charged Leyden jar. Thoughts then will arise as to how it gets into the atmosphere, and this being accounted for we may be at a loss to find any analogy between the atmosphere, and a Leyden jar, and therefore we may not see clearly how the air can become charged so as to receive and deliver up a charge of fluid in so distinct a manner as in a flash of lightning. These doubts we will endeavour to remove. First. Its presence in the atmosphere may easily be imagined from the experiments with the gold leaf electrometer in page 9, and still more so from the electricity of evaporation in page 22 ; indeed, evaporation alone is amply sufficient to account for all the effects which take place. Although the evaporation of a few drops of water manifest but a small effect, yet the whole amount of the fluid thus disturbed may be imagined, by stating that 5280 millions of tuns of water, are, as is imagined, evaporated from the Mediterranean Sea alone in one summer's day. It must be observed also that other causes are always in action, as currents of wind impinging upon the earth's surface, the motions of all bodies, chemical change, &c., sometimes adding to this accumulation, sometimes decreasing it; and thus it is that different parts of the air are differently electrified at the same time.

The next question to clear up is the manner in which the atmosphere becomes charged to the degree, and in the manner of a Leyden jar. This also may be illustrated by direct experiments, which will not merely show the fact that it does become so charged, but also

how other electric atmospheric phenomena take place, and to what cause may be ascribed many of the phenomena which are observed in the course of common electrical experiments. It may be more fully proved as follows :—

394. Cover two large boards with tin-foil, suspend one by silken strings from the ceiling, and then connect it with the conductor. Place the other board parallel to the former, on an insulating stand that may be easily raised or lowered to regulate the distance of the plates from each other. Or place the boards in a vertical situation parallel to each other, on insulating stands of the same height. In most cases this form will be found more convenient. These boards may be considered as the coating to the plate of air which is between them. Connect one of the boards with the prime conductor, and the other with the ground ; turn the cylinder, and that one which has been united to the prime conductor will be electrified positively, while the other will be negative. The space of air between the two plates acts as a plate of glass, it separates and keeps asunder the two electric powers. Touch the negative plate with one hand, and the positive plate with the other, and a shock will be received similar to that from a Leyden jar.

395. Place half a ball or any other eminence on the lower plate, supposing them to be horizontal. The spark in this case will strike the eminence, and the plate of air be discharged. The experiments with these boards will be more pleasing if one surface of the upper board is covered with gilt leather. The two plates when charged are supposed to represent the state of the earth and clouds during a thunder storm ; the clouds being in one state, and the earth in another.—*Adams.*

396. *Pillars of sand and whirlwind imitated.*—Place bran or small pieces of paper in the middle of the lower board. When the machine is put in action, these will be alternately attracted and repelled with great rapidity, and agitated in an amazing manner. This experiment is very similar to that of the dancing figures, *Ex.* 136, but owing to the very much greater size of the boards, and the lightness of the objects, a very curious phenomenon is generally observed, namely, that each particle of bran turns on its axis at the time it is moving up and down ; and if the electricity be strong, the whole unite into a column which turns on its axis, and often rolls along until it arrives at the edge of the board, where it flies off. This experiment is an exact imitation of a *whirlwind*, and also of the *rolling pillars of sand* which are so much a terror to the African traveller.

397. *Imitative earthquake.*—Place a building, which is formed of several loose pieces of wood, on a wet board in the middle of a large basin of water ; let the electric flash from a battery be made to pass over the board, or over the water, or over both, the water will be strongly agitated, and the building thrown down.

398. If a long narrow trough of water be made part of the circuit in the discharge of a battery, and a person's hands be immersed in the water at the time of the explosion, he will feel an odd vibration in the water, very different from an electrical shock. The quick stroke from the repercussion of the air and the vapor is communicated to the hand by the water, and the hand receives a shock similar to that received by a ship at sea during an earthquake.

399. *Glaciers imitated.*—The cause of the irregularity on the surface of glaciers has been much discussed of late years, and among other theories it has been supposed to have arisen from the passage of strong currents of electricity over them. This theory is somewhat supported by passing a strong shock over the surface of a sheet of ice, which becomes impitted with numerous cavities and irregularities, similar to, but of course on a much smaller scale than in nature.

400. *Aurora Borealis.* — This is admittedly electrical, and is so easily and exactly imitated as to leave no doubt of the fact. We will refer to the experiments in *Vacuo*, described in page 51, where this phenomenon is explained : and the identity becomes the more evident from the circumstances that whenever it appears, the atmosphere is found replete with the electric fluid ; and, secondly, because it equally with electricity affects the magnetic needle. It puts on appearances different from lightning because it occurs at a considerable elevation above the earth, where, as before explained, the air is much rarefied.

401. *Falling stars.*—Whenever the electric fluid is at a more moderate height, and in a more concentrated form, it occasions those electrical appearances, known to us as falling stars or meteors ; these are generally considered indicative of rain, and not without some cause, inasmuch as rain, hail, snow, &c. are always produced by any sudden electrical change that takes place.

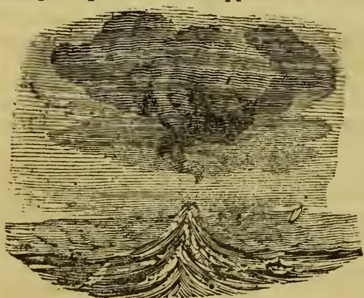
They may be imitated by passing a shock through a long exhausted tube, similarly constructed to that described and figured as the *Aurora flash*, page 51, but not exceeding ½ an inch in diameter.

402. *Rain, snow, &c.*—It has been said by some that the reason rain, &c. falls in

drops, and still more so, why snow appears in light fleecy flakes is owing to electrical repulsion, as is somewhat proved by the experiment of the expansion of a fleecy feather when driven off by an excited tube, and also by the spun sealing-wax.

403. *Fiery rain.*—Thus also can we in some degree explain the fiery rain mentioned in the Scriptures, and by various ancient writers, certain it is that every drop of rain which falls during a thunder-storm is charged with the fluid, and therefore contributes to divest the storm of its fury.

404. *Waterspout.*—The waterspout, that wonderful and terrific object, is too easily explained by electric attraction to leave any doubt that its cause is a highly-charged state of the air, and we are confirmed in this conclusion by the means taken to disperse it, namely, by firing cannon and pointing sharp weapons at it. *Ex.* 154 and 155, show effects very analogous to the waterspout. The following cut gives the usual appearance of this



terrific phenomenon; the sea beneath it is agitated, and rises up in a short column; the cloud above stretches downwards in the form of a funnel, sometimes remaining steady, but more frequently moving forwards, and involving in destructive torrents of water every thing it touches; and so great is often its power, as to draw up fish and other objects: hence the frequent accounts we read of *showers of frogs, fish, &c.*

IDENTITY WITH LIGHTNING.

The identity of the electric fluid with lightning was one of the first-established facts relative to atmospheric electricity, and as it was the first in time, so it is also in importance to us, teaching not merely the origin and properties of that mighty power of nature, but also how to escape from its direful effects. The very appearance of lightning would induce us to attribute it to electricity, nor is this supposition in any way weakened by our experimental researches. If we compare the properties of electricity with those of lightning, we shall find them closely analogous, or rather identical.

405. *Lightning destroys animal and vegetable life, so does electricity.*—Procure a mouse, and send a strong shock through his body from head to tail, and the poor animal will instantly fall dead. To pass the shock through the head or chest seldom kills, but if it pass along the spinal marrow it always does, the tail should therefore always form part of the circuit.

406. When the animal is dead, pass a second shock in the same manner as that which killed it, and the fluid instead of passing through the animal will pass over it, and consequently be luminous. This is a curious experiment, as it shows that the substance of the animal ceases to be a good conductor with its life. It is a well-known physiological fact, that in the bodies of persons killed by lightning, as well as of animals killed by an electrical shock, the blood does not coagulate, but very soon becomes putrid, and the flesh black. Lightning passing over the skin of a person scorches it in the same manner as an ordinary flame would do, and the after sensation is very similar.

407. Pass a very small shock through a flounder, or other fish, and it will be deprived of life instantly.

408. Put several fish into a basin of water, and send a shock through the water, the fish will be killed in a moment.

409. Pass a strong shock from the top to the root of a balsam or geranium plant, and although no immediate effect will be apparent, yet the plant will be effectually killed, as will be evident after a few days.

The effect of lightning in destroying various things opposed to its passage, in setting fire to combustible substances, rending trees and disturbing the magnet, we have shown in the chapter on the mechanical and other effects of electricity to be easily occasioned by the rapid progress of the fluid through them. Their identity therefore is clearly established, and the importance of electricity as well as its universal agency, becomes more conspicuous as we advance. Our preservation from lightning is evidently of the first importance, and the manner best to accomplish this was first suggested by Dr. Franklin. Soon after his important discovery of the true nature of the electric fluid, he pointed out the utility of conductors to buildings. The necessity of these was admitted by all, but philosophers could not agree among themselves as to these conductors, whether they should be terminated by a point or a ball. Those who contended for the superior efficacy of a ball, maintained that a point drew the fluid from a greater distance than a ball, and therefore the cloud was as it were invited towards the building. As many

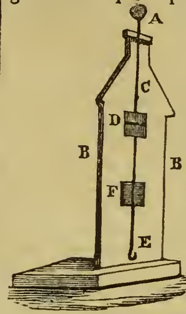
experiments were brought forward in furtherance of these arguments, it had many supporters, till Franklin, by his ingenious explanation of their experiments, and one of his own, set the matter for ever at rest. The following experiments are those now alluded to :—

410. Fasten the head of hair of *Ex.* 129, or the glass feather of *Ex.* 128, to the prime conductor, and turn the machine, while the hair or the filaments of the feather are divergent, hold towards them a ball; the filaments will immediately be attracted, and will cling round the ball ; but hold a point instead of the ball, and they will be repelled.

411. *Franklin's cloud.*—Fasten three loose pieces of cotton wool upon a linen thread, so that they shall hang at about 2 inches distance from each other, or else fasten three fleecy feathers in the same way. Adjust this apparatus to the prime conductor, turn the machine, and hold a ball and point alternately to the outermost feather. When the ball is held, the feathers will clasp the ball, but when the point approaches, the first feather recedes to the second, the second to the third, and the third to the conductor.

These experiments apparently prove that the fluid is more attracted by the ball than the point, but this conclusion is erroneous ; the reason of the recession of the feathers in the last experiment is not because they are repelled by the point, but because the point rapidly deprives the outermost feather of its fluid, and then that feather being in a neutral state retires, or is attracted to the next. The point acts in like manner upon this, which occasions them both to retire and so on. Thus it is with a pointed lightning conductor, it draws off the fluid from a thunder cloud so rapidly as to take away the cause of danger. It is however to be tested, whether in neutralizing the cloud it does not endanger the building ; this is not so, provided the conductor is perfect, and offers a continuous metallic course from the fluid to the ground, its ultimate destination. If the conductor be inadequate, it will be melted, if it be interrupted, although it be pointed, yet a shock will as readily pass along it as if it were terminated by a ball, and as we have seen from experiments in a former chapter a concussion and consequent injury must always take place when this is the case. The following apparatus are peculiarly adapted to show the truth of this position :—

412. *Thunder house.*—This ingenious article is made of an upright piece of baked mahogany, formed like the gable of a house, as B B, and placed upon a wooden stand. A wire marked C runs downwards throughout its whole length. It is terminated above by a ball A, which being unscrewed shows a point beneath it. In one or two parts of the gable are square pieces of wood cut out.



These are ¼ of an inch thick, and 1 inch square on the side. They are shown at D and F ; are made so as to fit loosely into a hole cut partly into the gable to receive them, and have a wire running across each, so placed, that putting in the pieces in one way, the wires shall with C E form a continuous and uninterrupted line, and when put crosswise, there shall be a want of contiguity at that place, as shown at D.

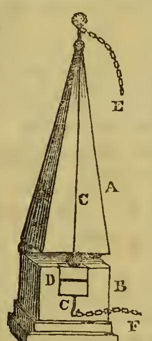
413. Pass a shock from A to E, while the ball remains on and the wire is continuous, and it will make a loud report, without disturbing either piece of wood.

414. Pass a shock, or rather endeavour to do so, with the upper ball taken off, so that the point is displayed. The fluid will pass and discharge the jar, but not in the manner of the shock, and no report will be heard.

415. Now place either of the pieces of wood crosswise, and restore the ball to the top. The shock will pass and throw out the piece of wood that was placed crosswise, but not disturb the other piece.

416. Let the piece of wood be placed crosswise, as in the last experiment, but remove the ball. Upon discharging the Leyden jar, a real shock will pass, and the wood will be displaced, although a point terminates the apparatus.

417. *Electrical pyramid.* — This is an apparatus of the same nature as the last, and is to be used in the same manner.



A is a four-sided pyramidal piece of wood, or more usually consists of four pieces fitting on to each other. A line runs down the whole in front, and is moreover continued down the base B ; continuity being occasioned by a small square, as in the thunder house. This is marked D in the cut, and is seen with its wire placed sideways. Upon this moveable square, and upon the back of the base, the upper portion is supported by three balls. When a shock is sent from E to F, the square D is thrown out, and the upper part of the pyramid falls.

Thus it is proved, that lightning conductors should be sufficiently large, lest they should be melted, and continuous lest they should give a shock rather than draw off the fluid silently and harmlessly. Also we learn from *Ex.* 197, and following, that the point with which they are terminated above should project for some height above the highest parts ot the building. Thus it is that chimnies are so often injured, but not from this cause alone; they being lined with soot, which is a good conductor, induces the flash to take that course. Therefore during a thunder storm it is dangerous to get near a lofty tree or a prominent chimney, so on a plain; even a sheaf of corn is sufficient to direct the course of the lightning, inasmuch as straw is a good conductor, though not so good as the human body; thus life would be endangered, for the fluid always takes the best conductor.

Strange as it may appear, yet it is a fact, that many persons are killed without any electric matter passiug through them at all, and thus we are not wholly safe even when the storm is wasting its fury upon other objects. This is easily accounted for by electrical induction, as follows :—When a charged cloud passes over a man, it affects all the fluid in his body, for as the fluid repels itself, the natural quantity he possesses is driven to his feet, which therefore become electrified positively, or have more than their natural share, while his head becomes negative. As soon as the overhanging cloud is discharged by striking a tree, rock or other object, the equilibrium of his body is immediately restored, and that with such impetuosity that convulsion or death is the consequence. Birds roosting in trees are thus often killed, or in cases where death does not ensue, blindness is the frequent result.

CHAP. XII.

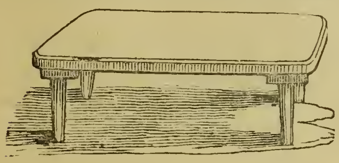
MEDICAL AND ANIMAL ELECTRICITY.

This part of the subject, although of importance in a physiological point of view, yet scarcely is entitled to a place here, because of its yielding few or no experiments; a short account however of administering electricity medically may be advantageously admitted; and we would premise the account by stating, that electricity should always be administered gently at first, and its power only increased when the gentle application is found ineffectual, except in cases of paralysis, or when used to remove obstructions; its full power may be at once administered; but even here the shock of a quart Leyden jar should never be exceeded; the frequency of the shocks, and not the strength of them being most to be relied upon. Also we would remark that no danger to life can arise from the administration of electricity in any way, unless, as before observed, it be sent along the spine, or perhaps through the brain. We have been more than once thrown down by the power of the shock, but even by the passage of a large battery through the arms have felt no ill effects, unless perhaps a slight head-ache. Strong shocks are however extremely unpleasant, and we trust that our experimental friends will not operate with any but a small jar, at all times, unless a large number of persons are to receive the charge, and even then to be very careful to exclude young children and delicate persons, as the fear alone may occasion distressing effects.

Electricity, according to the mode of its administration, is either sedative, stimulant, or deobstruent; hence the propriety of its application to diseases of quite contrary character. We have applied it to palsies, rheumatisms, inflammations, contractions of the muscles, amaurosis, chilblains, tumours, sprains, and other diseases and accidents. The methods of electrifying are five; first, simple electrization, or merely subjecting the person to the action of electricity, by placing him on a glass-legged stool, and connecting him with the electrical machine when in use. Second, drawing the fluid from the particular part of his body which may be affected; this is either done holding towards him a wooden point.

when a cooling and refreshing breeze is perceptible, or by placing your hand upon his clothing, when if any woollen or silk interpose between your hand and his body he will feel a peculiar pricking sensation, occasioned by innumerable sparks issuing from the part beneath the hand, and which will soon occasion a great degree of warmth in that part. Or a third method is to draw the fluid from him by means of sparks, taken by the knuckle, or else by a wire with a metallic ball at the end of it. If the operator hold this tight he will not feel the sparks himself. A stronger way of drawing off electricity is by means of what are called *vibrations*, and a still stronger, *sparks*. For these two last the patient either stands, or sits on an ordinary chair, and not on the glass stool before mentioned.

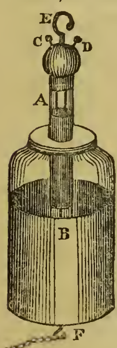
The following apparatus is all that is essentially necessary, though many other articles have been described and recommended. The first essential is a glass-legged stool; if required for cheapness it may be a piece of board, made smooth, and with round edges, supported upon four wine bottles, pegs being driven into the under-side of the board to fit the necks of the bottles; solid glass legs are, however, infinitely better. In using the stool, a large sheet of brown paper or pasteboard; or, still better, a piece of oil-cloth, larger than the stool itself, is to be placed beneath it on the floor, to prevent the filaments of the carpet, or the dust of the floor, from drawing away any of the fluid accumulated.

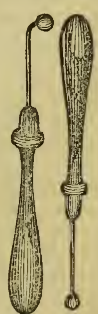


The next requisite is a flexible tube or connector; as a chain must necessarily have many edges or points, the stool should be connected to the machine by a chain which is sewed up in silk, and afterwards varnished or covered with India rubber; thus there will be no loss of fluid. But for numerous purposes the instrument called a flexible tube is much better. This is explained in page 63.

A wooden or metal point is sometimes used; by this a gentle stream of electricity, is given to or taken from a patient, according as the point is held in the hand of the operator, (the patient being on the electrical stool,) or attached to the glass-handled flexible tube, the patient being on the ground, or rather not insulated. These simple instruments, with the exception of a wire with a brass ball at the end of it, are all that are necessary for the administration of the electric fluid, except when shocks are to be given. In this case a Leyden jar is indispensable. Any Leyden jar may be used, but the one shown, and described beneath, is most convenient for medical purposes.

Medical Jar.—This is like an ordinary Leyden jar, covered and lined to a certain height with tin-foil, as at B. A wooden cap is then prepared for it, and a hole just admitting a glass tube A, is bored in the middle of the cap. The tube reaches below to within 2 inches of the bottom, and projects upwards above the cap, about 3 inches. This tube is also partly lined and covered with tin-foil, so placed that rather more than an inch of the glass is left uncovered at the lower end, and about 2 inches at the upper end. The tube is cemented to the top of the bottle, and a smaller cap cemented on the top of the glass tube; but before this last is cemented on, three hooks are drilled in it; one for a hook wherewith to suspend the phial from the conductor, the two others are to be left open; one of them to admit a wire to touch the inner coating of the tube, the other a second wire, sufficiently long to reach to the coating of the phial—these are shown in the cut at C and D. A wire is also twisted round the outer coating of the inner tube, which projects outwards sufficiently to touch the inner coating of the phial. On the outer coating of the phial is fastened a hook, marked F, for the convenience of attaching a chain. This bottle is always used in connexion with the medical electrometer, described in page 56; and also with a pair of *directors*, glass-handled instruments, shown in the margin.





These directors are for two purposes, first, that by means of their balls they shall be able to direct the fluid or shock to any particular part only, and confine it thereto; and secondly, that the operator, holding the glass handles, may not participate in the shock, which passes in a straight line from the ball of the one director to the ball of the other, when they are respectively connected by chains, the one to the outside of the medical bottle, the other to the sliding piece of the electrometer. When both wires are in the bottle, the

the whole bottle is chargea, and the strength of the shock is considerable; but when the longer wire is drawn out, the only one left will be that which touches the inner coating of the tube, and this tube being so small, the shocks which will pass will be less energetic than those given by the larger bottle, and will altogether have a different character. They are, indeed, intermediate in effect between sparks and shocks, and are called *vibrations.*

Animal electricity partakes more of the nature of galvanism than that free state of frictional electricity, which is our present subject. The power of giving shocks appears wholly confined to fish ; no species of any other race of animals, having any power analogous to the complicated apparatus found for this purpose, applied to the electrical eel and the torpedo. Several of the former of these fishes have of late years been brought to this country, and experimented with. The shock is indeed sudden and momentary, like that from a Leyden battery, but the effects when a continual current is produced by connecting the head and tail of the animal in decomposing water, forming and disturbing a magnet, giving a faint spark only, even under the most favorable circumstances, and giving the shock only when the circuit is wholly formed of good conductors, (requiring even the hands to be wetted,) and the whole of its electrical power taking its origin among wet, fleshy, and dissimilar animal substances, show the propriety of excluding an account of the animals, interesting as is their nature and wonderful their powers.

CHAP. XIII.

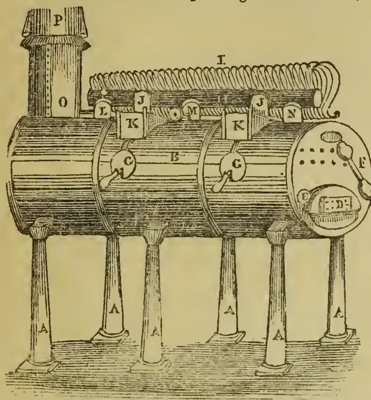
HYDRO-ELECTRICITY, OR ELECTRICITY OF WATER.

The fact that the issuing of steam through an orifice should give rise to electrical appearances was not merely unknown, but not even suspected, until little more than three years since, when an account appeared in the *Philosophical Magazine*, that the boiler of a steam engine near Newcastle being defective, (the joint or flaunch of the safety valve having given way, so that the steam, which was at a pressure of 35 lbs. per square inch, was issuing forcibly through the aperture,) a Mr. Patterson, who was standing near, upon touching the weight of the safety valve, felt a pricking sensation in the fingers. A few days afterwards the same being repeated, induced a greater attention to the subject, when a spark was elicited ; and proper apparatus being procured, a shock, and other electrical phenomena. Thus this wonderful discovery was made, and as it may well be imagined soon bruited abroad, drawing the attention of philosophers to the subject; particularly the indefatigable and erudite chemist and electrician, Professor Faraday, who has lately read a paper to the Royal Society, entitled, " On the Electricity evolved by the Friction of Water and Steam against other Bodies." The object of the experiments detailed in this paper is to trace the source of the electricity which accompanies the issue of the steam. Professoı Faraday relates that electricity is never excited by the passage of pure steam, but only when water is also present; hence he concludes that it is altogether the effect of the friction of globules of water against the sides of the opening, urged forward by the rapid passage of the steam. The effect of this is to render the steam or water positive, and the pipes from which it issues negative. Heat, by preventing the condensation of steam into water, likewise prevents the evolution of electricity, which again speedily appears by cooling the passages, so as to restore the water which is necessary for producing the effect. Water will not excite electricity unless it be pure; the addition to it of any soluble salt or acid, even in minute quantity, is sufficient to destroy this property. The addition of oil of turpentine, on the other hand, occasions the development of electricity of an opposite kind to that which is excited by water. A similar and more permanent effect is produced by the introduction of olive oil along with the water. Similar results were obtained when a stream of compressed air was substituted by steam.

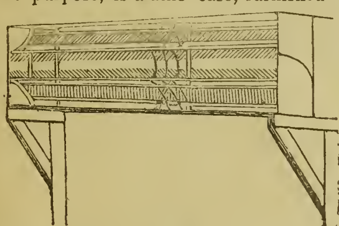
These experiments and conclusions of Professor Faraday are interesting, and the more so, as by them we are able to show by fact what we could before these discoveries only infer, namely, the mighty power called into action by the currents of air, vapor and moisture of the atmosphere; indeed, it is evident, that a gun cannot be discharged, not even an air gun, nor yet a common tea kettle give steam from its spout, without exciting the electric fluid, nor is it in small quantities either, as the following account of the largest and most powerful electrical machine ever constructed will show. It is that machine now in

use, and daily exhibited at the Polytechnic Institution, Regent Street, London, and known as Mr. Armstrong's hydro-electric machine, that gentleman having been the maker of it, and its power being derived from the friction of water as above described.

A A A A A A are six green glass supports, 3 feet long. B is a cylindrical tubular boiler of rolled iron-plate $\frac{5}{8}$ inch thick; its extreme length is 7 feet 6 inches, 1 foot of which is occupied by the smoke chamber, making the actual length of the boiler $6\frac{1}{2}$ feet: its diameter is $3\frac{1}{2}$ feet. The furnace D, and ash-hole C, are contained within the boiler; and are furnished with a metal screen to be applied for the purpose of excluding the light, during the progress of one class of experiments. F is the water guage; E the feed-valve. J J, are two tubes leading from the valves K K to the two tubes H. A and I are forty-six bent iron tubes, terminating in jets; either half or the whole of which may be opened by means of the levers G G. L is a valve for liberating steam during the existence of the maximum pressure. M is the safety valve; N is a cap covering a jet, that is employed for illustrating a certain mechanical action of a jet of steam. O is the first portion of the funnel, P the second portion, which slides into itself by a telescope joint, so that the boiler may be insulated when the experiments commence. The boiler is cased in wood.



The next figure, which may be called the prime conductor, but which is not used for that purpose, is a zinc case, furnished with four rows of points. It is placed in front of the jets, in order to collect the electricity from the ejected vapor; and thus prevent its returning to restore the equilibrium of the boiler. The maximum pressure at the commencement of the experiments is 80 lbs.; which gradually gets reduced to 40 or lower. The portion of the apparatus, which is peculiarly connected with the generation of the electricity, is a series of bent tubes with their attached jets. Each jet consists of a brass socket, containing a cylindrical piece of partridge wood, with a circular hole or passage through it, $\frac{1}{8}$ of an inch in diameter, into which the steam is admitted through an aperture. The peculiar shape of this aperture appears to derive its efficacy from the tendency it gives the steam to spread out in the form of a cup, on entering the wooden pipe, and by that means to bring it and the particles of water, of which it is the carrier, into very forcible collision with the rubbing surface of the wood.



The electricity produced by this engine is not so remarkable for its high intensity, as for its enormous quantity. In no case, antecedent to this, has the electricity of tension taken so rapid a stride towards assimilating with galvanic electricity. Mr. Faraday's experiments on the identity of the electricities had shown how small was the quantity obtained from the best machines; and had given good reason to expect that chemical effects would be exalted when the quantity could be increased. And such is the case here; a very remarkable experiment in illustration of this is, that not only is gunpowder ignited by the passage of the spark, but even paper and wood shavings will be inflamed when placed in the course of the spark passing between two points — such an effect was never before produced with common electricity. In like manner, chemical decompositions are effected much more readily by means of the hydro-electric, than by that from the common machine. The current, when passed through a galvanometer, caused the astatic needle to oscillate between 20° and 30°; it also formed an electro-magnet, which deflected a needle. In these various experiments care is taken to place the conductor very near the jets when quantity is required, and to remove it beyond the striking distance for intensity.

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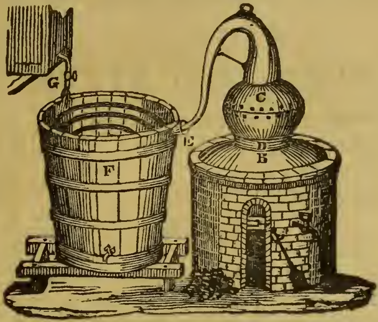

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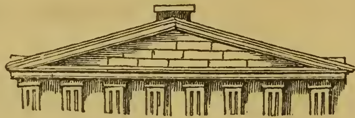

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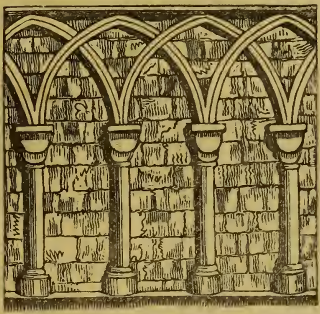

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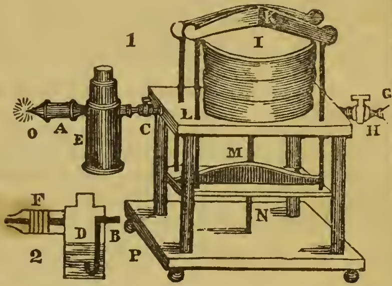

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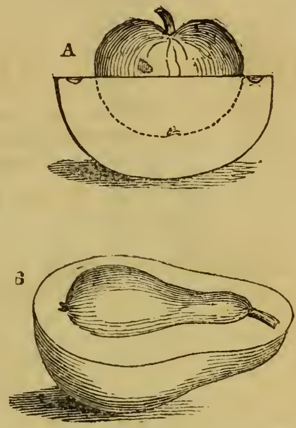

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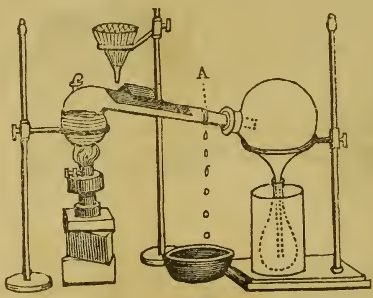

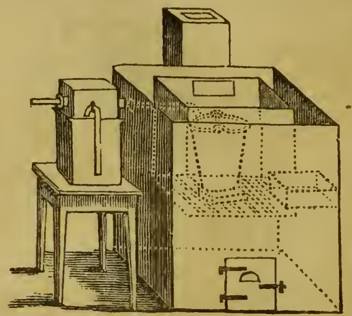

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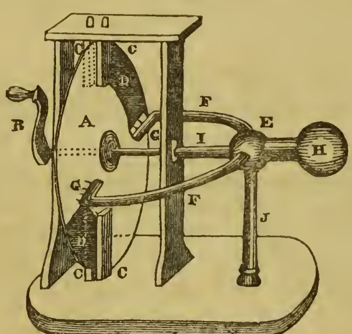

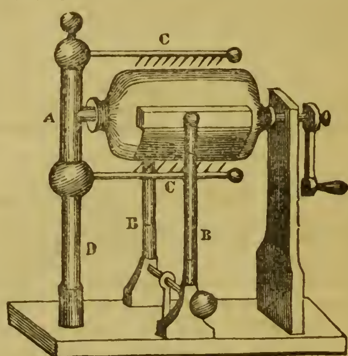

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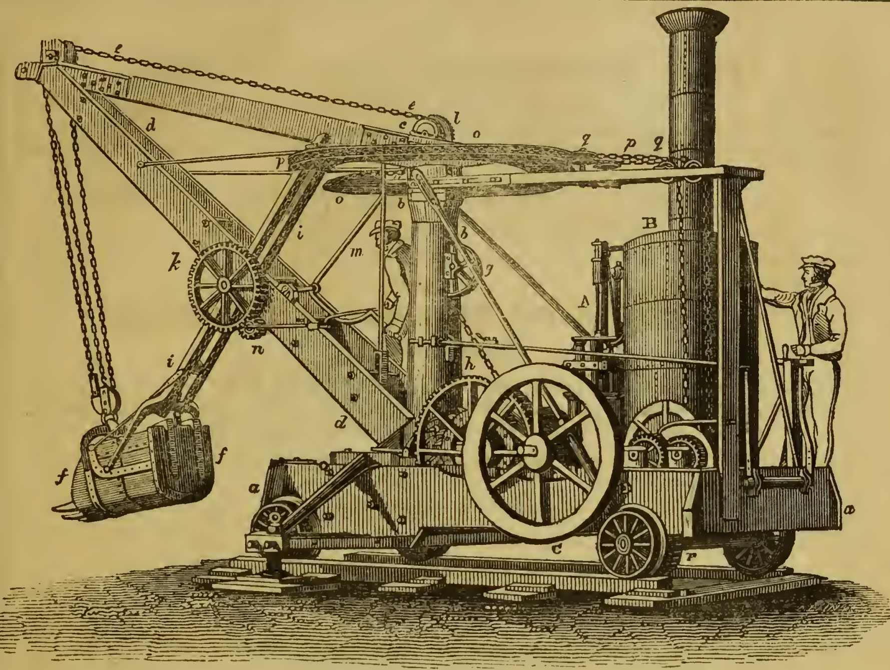

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No. 41. Steel Mixture, (Three Receipts)—Steers's Opodeldoc—Steinacher's Nitric Acid—Stephens's Remedy for the Stone—Stereotype Plates, Alloy for—Sterry's Plaister—Stimulant Enema—Stimulant Liniment—Stimulant Mixture—Stimulant Plaister—Stoerck's Pills—Stomachic Draught—Stomachic Electuary—Stomachic Elixir—Stomachic Tincture—Stomachic Wine—Stopping-out Varnish—Storax Pills—Storey's Worm Cakes—Storm Glass for foretelling the Weather—Stoughton's Elixir—Strains, Embrocation for—Stramonium Lincture of—Stramonium Ointment—Stranguary, Treatment of—Strawberry Jam—Strawberry Wine—Straw Bleaching—Struve's Lotion for Hooping Cough—Strychnine Mixture—Strychnine Pills—Strychnine Spirit of—Styptics—Styes in the Eye-lids, Treatment of—St. Yve's Eye Ointment—Succedaneum, Mineral—Sugar to Boil and Clarify—Sugar Candy—Sugar Rock—Sugar Vinegar—Sulphate of Zinc Ointment—Sulphur, Balsam of—Sulphur Bleaching by—Sulphur Coins, to make—Sulphur, Electuary of, Simple, and Compound—Sulphur Lozenges—Sulphur, Milk of—Sulphur Moulds for Medallions, &c.—Sulphur Ointment—Sulphur, Precipitated Milk of—Sulphur Seals, Medals, Coins, &c.—Sulphur, Tincture of—Sulphur, to obtain Pure—Sulphuret of Mercury Cerate—Sulphuric Acid Ointment—Suppository, Purgative, Sedative and for Worms—Swinton's Daffy's Elixir—Sydenham's Lenitive—Sympathetic Inks, viz. Black, (Two), Brown, Blue, Yellow, Red—Syrian Garnet, to Imitate—Syrup Cream, or Cream Syrup—Table Ale—Table Beer—Tain, Eau de, (Thyme Water)—Talc Water—Talc, Oil of—Tamarinds, Conserve of—Tamarinds and Senna—Tannin Ointment—Tar Ointment—Tar Varnish—Tar Water—Tartar Emetic—Tartar Emetic Mixture—Tartar Soluble—Tartar, Soluble Cream of—Taylor's Defensor, &c. &c.

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No. 43. Velvet, &c., Colors for Painting on—Venus, Huile de—Veratrine, Liniment—Veratrine Ointment—Verdigris—Verdigris, Liniment of, Ointment, Plaister—Verditer, Blue—Verjuice Water for Iceing—Vermicelli—Vermifuge, or Worm Mixtures—Vermillion—Vervain's Balsam—Vidonia Wine, to Fine—Viganis' Elixir of Vitriol—Vinaigre Dentifrique, Cosmestiques—Vinegar, to make, Ointment—Violet Powder, Perfume, Syrup of—Vitriolic Elixir—Vitriol, Sweet Spirits of—Wafers, Manufacture of—Wafers, (in Cookery) Walker's Jesuit's Drops—Walls, to preserve from Dampness—Walnuts to Bleach, Extract of, to Pickle, Ketchup—Want's Powder—Ward's Antimonial Pills, Essence for Head-Ache, Paste for the Piles, Sweating Powders, White Drops—Ware's Golden Ointment—Warner's Cordial—Warming Plaister—Warts—Wash Balls—Wasp, on Swallowing a—Watchmakers' Oil—Water Cement—Water Color Cakes—Waterloo Crackers—Water-proof Boots, Cloth—Wax, Bleaching and Purifying of, Imitations of, Candles, Imitative Lute or Cement, Ointment—Webster's Antibilious Pills, Diet Drink—Wedel's Oil—Wedgewood Composition of Mortars—Weeds, Extirpating—Welsh Ale—Weld Yellow—Westphalian Essence of Wood Smoke—Whipt Cream—White Briony, Extract of, Camphorated Ointment, Enamel, Hellebore, Extract of, Lotion or Wash, Metal, Precipitate, Precipitate Ointment—Whitlow—Whortleberry Mixture—Whyte's Tincture of Bark—Wigg Cakes—William's Stucco—Wilson's Prepared Asphaltum—Windsor Ale, Soap—Wine Bitters—Wines, to Fine or Clarify, to Correct when Harsh, to Correct when Acid, to Clear Foul or Ropy—Wine Vinegar—Wood Staining.

No. 44. Wool Bleaching—Worms—Wormwood, Conserve, Extract, and Essence of—Writing Fluids—Wych's Stucco—Yeast, to Preserve, Substitutes for, and Poultice—Yellow Dipping Metal, Dyes, Ink, Lotion or Wash, Resin Soap, and Stain for Glass—Yolk of Egg Ointment—Yorkshire Oat Ale—Young's Purging Drink—Zaffre and Smalts—Zincing—Zinc Labels, Ink for Writing on—Zinc Lozenges—Zinc Ointment—Title, Preface, Introduction, Tables of Weights, &c. &c

Date Due

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